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THE COINAGE OF ROME.

By G. F. Hill.

THE coinage of Rome, and of those parts of the Italian peninsula which did not come most directly in contact with Greek civilization, offers a striking contrast with the coinage of Greece.* Whereas, in the first place, the latter began with the more precious metals, Italy at first contented herself with bronze (*aes*) as her medium of exchange; for the coinage of silver and gold, though these metals were well known, was not introduced until comparatively late. And as Roman civilization generally was some centuries behind that of Greece, it is not until the middle of the fifth century that coinage, properly speaking, can at the most liberal estimate be conceived to have begun in Rome; while there are reasons for putting the commencement nearly a century later. Previously to the commencement of coinage proper, the medium of exchange in Italy, as in other parts of the world, had been cattle, values being reckoned in so many oxen or sheep. The transition from this system to the money system was made by the use of amorphous lumps of bronze (*aes rude*) which circulated by weight. Such pieces of metal cannot be called money, any more than their predecessors the sheep and oxen, and therefore as numismatists we are only secondarily concerned with them. It is, however, worth noting that long after *aes rude* had been superseded by coined money, it was retained in use for certain special purposes. It was retained, for instance, together with the scales in which it was weighed, to perform a ceremony necessary to the validity of the transfer of certain kinds of property. It was also frequently devoted as an offering to various deities, in the localities of whose shrines large quantities have been found.

It is with the *aes signatum* (bronze marked with a design) that our description of Roman coinage must begin. Some authorities, as we have already said, refer the beginning of this coinage to the middle of the fifth century before Christ, and this view is based on literary tradition; but even if the literary evidence can bear the interpretation put upon it, it must always yield to the evidence of coins themselves. And a comparison with the coinage of the rest of the world proves conclusively that the earliest pieces which have come down to us belong to the fourth century, and by no means to its earliest years.

We meet at the outset with an important difference from Greek usage as regards the method of coinage. Greek coins were, almost without exception, struck with a die; but the bronze coinage of Italy was cast in a mould, and the reason is obvious. The small value of copper as compared with silver and gold necessitated the use of large masses of metal to represent high denominations; and to strike such large masses with a die requires skill and power which are difficult to provide even in modern times, not to mention the fact that few dies would stand the strain. The metal was, therefore, given the required form by casting, and even in later times the officials of the Roman mint retained the title of "commissioners for *casting* and striking bronze, silver, and gold." In some of the pieces projections at the sides of the coin mark the points at which the liquid metal entered the mould (Fig. B).

The earliest cast coinage took, for large denominations, the shape of oblong bricks of metal, weighing from four to five Roman pounds (Fig. A). Probably contemporary with these are the smaller pieces of the more convenient circular shape (Fig. B). This is what is known as *aes grave* ("heavy bronze," so called, of course, in comparison with the lighter coinage of later days). The large size of the early pieces necessitated a thick as well as a broad fabric. But with the gradual decrease in size of the pieces, which we shall describe later, we arrive at a fabric hardly differing from that of the Greeks. For about 269 B.C. the smaller bronze coins were struck instead of cast, and some twenty years later the process of casting ceased entirely to be employed.

About the same time as the *aes grave* was introduced the extension of the power of Rome over the peninsula had compelled the Romans to adopt the customs of their South Italian neighbours, and issue coins in silver and even in gold. But it is characteristic of Roman conservatism that the first coins in these metals struck by Roman authority were struck, not for Rome itself, but for the subject states, or rather as war money, to be used in the wars waged by Rome against the Samnites, the Greek general Pyrrhus, and the Carthaginians. About 342 B.C., when the Romans began to interfere with the affairs of Campania, the coinage hitherto issued by the cities in that district was replaced by pieces of silver, bronze, and (a little later) gold, issued by the Roman generals and bearing the name of the Roman people (Figs. 6 and 7). Still, it was not until some seventy years later that Rome struck

* *See* "Coinage of the Greeks," in Knowledge, June, 1895.

silver for her own use (269 B.C., Fig. 9). This date marks the practical cessation of the various independent coinages of Italy; almost all the cities now being compelled to issue only small change on their own account, and to use the Roman money for higher denominations. Gold still continued to circulate by weight, and indeed this metal was never reduced to a regular system of coinage until the time of Augustus. There are, it is true, instances of gold pieces being struck by the Romans. For example, besides the Campanian gold already mentioned, there was a considerable issue of gold (Fig. 8) during the second Punic War (in the end of the third century); but this was made solely for the purpose of carrying on the war in Southern Italy, and must be regarded, like the Campanian gold, as "money of necessity" rather than as regular coinage. The gold pieces, again, struck by Sulla (Fig. 15, Head of Venus, and Cupid; *reverse*, trophies and sacrificial instruments) and in a single hoard, buried seven years after his death, no less than eighty thousand pieces were collected.

The coinage of silver under the Empire was not so severely restricted as that of gold. At the same time, only a few mints were allowed to strike even in this metal, the largest series being those of Alexandria in Egypt, Antioch in Syria, and Cæsarea in Cappadocia (Fig. 20 shows the sacred mountain Argæus, near Cæsarea). The silver of these mints became rapidly debased, until it was no longer distinguishable from bronze. The actual bronze coinage of the Roman Empire may be divided into two classes. The first is that struck at Rome by the orders of the Senate (the ordinary "large brass" coins, marked with the letters S C—"by decree of the Senate"); the second is the money issued by the various cities of the provinces, from the Atlantic Ocean to the Euphrates. Of the vast quantity of bronze coins turned out by these mints, it is difficult even for the

FIG. A.—*Aes Signatum*, the Earliest Cast Coinage of Rome.

Pompey the Great in the first century were also no regular coinage, but were probably issued for show, or for distribution as presents. The coinage of gold was strictly forbidden in provinces where Rome had anything to say. But as in Greece Alexander the Great had signalized the universality of his rule by enormous issues of gold, so the universal empire of the Romans was marked by the imperial metal being placed at the head of the coinage of the world. Alexander had not been able to prevent the various Greek states issuing gold on their own account, but under Roman rule the use of this metal was much more strictly reserved to the Imperial exchequer. Some idea of the amount of gold issued by Julius Cæsar and his immediate successors may be gathered from the fact that specialist to form any conception; and a glance through a representative collection will do much to impress one with the fact that under the early Roman Empire the civilized world enjoyed a condition of material prosperity such as those who read only the history of the Roman court can never realize. After the time of the Emperor Gallienus (253-268 A.D.), the coinage shrinks considerably in amount, and there is no extensive series issued by any city on its own account, except Alexandria. We have now only the Imperial coinage, issued not only in Rome, but in provincial mints, such as London, Tréves, Lyons, Milan, Nicomedia, Antioch, Alexandria. The number of these Imperial local mints was further increased by Diocletian (284-305). From this time until the fall of the Roman Empire in

the West in 476 A.D., there is no important change to chronicle, except the rise of the Byzantine coinage, which, being an outcome of the breaking away of the civilized world from Rome, may well be left for consideration in connection with the coinage of Europe in the Middle Ages.

In the above sketch of the history of Roman coinage we have taken no account of the changes in the monetary standard. This, nevertheless, is a most remarkable feature, and must, at the risk of tedium, be dealt with in some detail. The Roman bronze coinage was based on the pound (*libra*) of bronze, and the mass of coined metal supposed to be equivalent to the pound was called *as*.

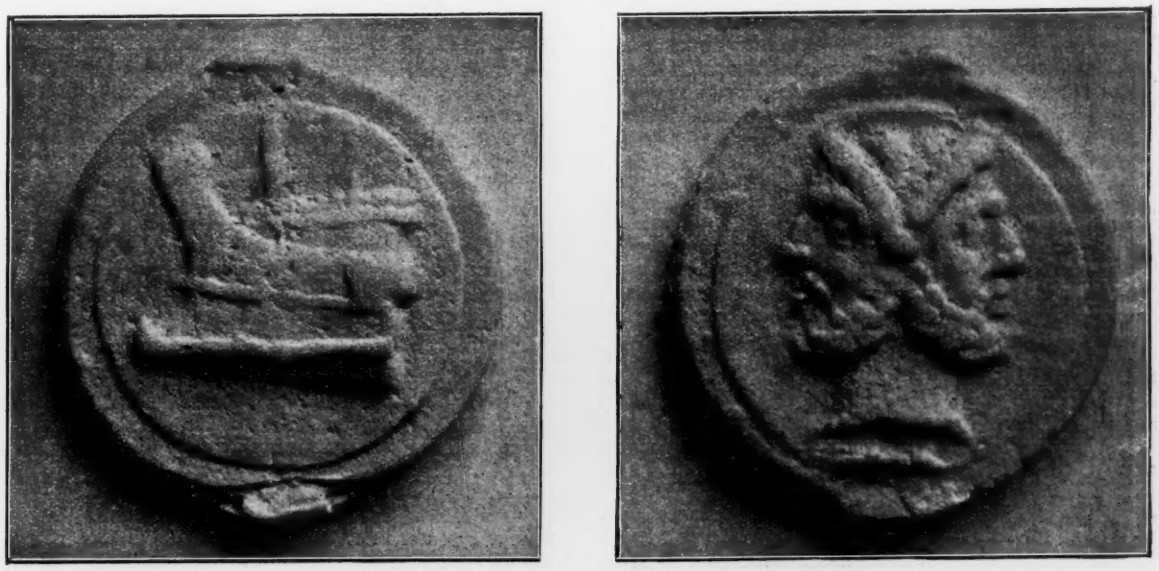

FIG. B.—*Libral As.* First Circular Coinage.

The *as* was divided into twelve ounces (*unciæ*), and the denominations (which were all, as we might expect from the practical Romans, marked with their value) were thus as follows:—

As	= 12 unciæ, marked with		I
Semis or Half	= 6	,, ,,	S
Triens or Third	= 4	,, ,,	••••
Quadrans or Fourth	= 3	,, ,,	•••
Sextans or Sixth	= 2	,, ,,	••
Uncia or Twelfth		,,	•

There were also multiples of the *as*, such as the *dupondius*, *quadrussis*, *quincussis*, and even *decussis*, of 2, 4, 5, and 10 *asses* respectively. And, at any rate later, there were divisions of the *uncia*.

As a matter of fact no extant specimen of the so-called "*libral as*" (Fig. B) is of the full weight of the *libra*, and it is clear that no attempt was made to attain exactness in weight. The *as* then began badly, and went through an extraordinarily rapid process of degeneration. The exact stages of this process are not certainly fixed, but they seem to have been somewhat as follows. The first great reduction took place in 269 B.C., when the *as* was reduced to a third of its former weight (*triental as*). About 250 B.C., the *sextantal as* (= two old *unciæ*) was recognized. In the second Punic war a third reduction took place giving the *uncial as*, and later still the standard fell one-half to the *semuncial as*. Thus in the course of some two centuries the bronze standard of the Romans was reduced to one twenty-fourth of its original weight. (Figs. 1—5 represent this gradual degradation, the *sextans* being selected as typical). This degradation, which is without parallel in the history of coinage, is only partially explained by the tendency of all heavy coinages to fall in weight. It is probable, nay more than probable, that soon after silver came into use, the bronze coins became more or less tokens; that is to say, they were given an arbitrary value, and their exact weight was, therefore, a matter of small importance. The poorer a metal is the greater is the tendency to use coins made of it as tokens rather than as pieces expected to realize their intrinsic value. A further explanation of the degradation is to be sought in the shrinkage which takes place whenever a cast is made. If the mould for one coin is made from another coin, the new coin in cooling will become slightly smaller than its model, and a third coin reproduced from the second will be smaller still.

The bronze coinage, which had been thus reduced to so insignificant a position, seems actually to have ceased about 88 B.C. It was not till the time of Augustus that the Roman mint again made a regular issue of bronze money, although generals like Julius Cæsar and Marc Antony struck bronze in the provinces.

With regard to the silver standard, it is only necessary to say of the Roman coins struck for the Campanian cities, that they conformed to the Greek standard already in use in that district, the stater (Fig. 7) weighing 112 grains and under. The unit of the silver coinage of Rome itself was the *denarius* (Fig. 9, weighing $\frac{1}{72}$ of a pound, equivalent to 10 *asses*, and marked with X); and the small denominations were its half (*quinarius*, V) and quarter (*sestertius*, $2\frac{1}{2}$ *asses*, represented by IIS, afterwards written HS). These marks of value cease to appear on the silver coinage about 90 B.C. In the Hannibalian war, when the *as* underwent its third reduction, the value of the *denarius* was slightly raised by lowering its weight from $\frac{1}{72}$ to $\frac{1}{84}$ of a pound of silver. At this weight it remained for more than three centuries, and the coins were never alloyed. At the same time the Roman mint openly indulged in the practice of issuing a

certain number of *denarii* of bronze plated with silver. These were mixed with the good coins in each issue, and there was no attempt to conceal the fact; and as the treasury was obliged to accept its own bad coin, these issues stand exactly on a level with the paper-money of our own times, except in so far as they made the way more easy for the private forger. Besides the denarius we have also to note the *victoriatus* (so-called from the figure of Victory erecting a trophy on the reverse; Fig. 10). This was first issued about 227 B.C., for circulation in Southern Gaul, Northern Italy, and Illyria, and was based on a unit equivalent to three-quarters of a denarius. But it soon went out of use again, its type being adopted for the quinarius. The quinarius itself and the sestertius both ceased before long to be issued regularly.

The Roman gold coins (Fig. 8) which were struck during the Hannibalian war also bear marks of value, but in terms of the sestertius, not the denarius. Thus—

↓X	=	60 sestertii	=	15 denarii
XXXX	=	40 ,,	=	10 ,,
XX	=	20 ,,	=	5 ,,

We have already alluded to the gold coins struck by Sulla and Pompey. Coins similar in character to these were struck by Julius Cæsar. Augustus issued an *aureus* (Fig. 16) equivalent in value to 25 denarii, at the weight of 40 to the pound of gold, and along with it a half-aureus. He also commenced a fresh issue of denarii, but adhered to the usual weight. His reforms in the coinage of small change were important. A large piece (Figs. 24, 25, 27, 28) called the *sestertius* (but wrongly, for it was equivalent to 4 *asses*) was issued, with its half (*dupondius*) and quarter (*as*), and smaller denominations. The denarius being equivalent to four sestertii was now equivalent to sixteen *asses*. The small change was merely a token-money, the *as* being nearly equal in size and weight to its double, the *dupondius*; but while the latter and the *sestertius* were made of yellow brass or *orichalcum* (copper alloyed with zinc), the *as* and smaller divisions were made of pure copper.

Such was the beginning of the Imperial coinage. But the degradation to which Roman coinage seems to have been peculiarly susceptible soon made itself apparent. By A.D. 215 the aureus was worth only $\frac{1}{50}$ of a pound of gold, and the denarius only contained 40 per cent. of pure silver. The Emperor Antoninus (commonly known as Caracalla) now introduced a new silver piece (*argenteus Antoninianus*, Fig. 21), worth half as much again as the denarius, from which it was distinguished by having the Emperor's head in a radiate crown (instead of laureate), or the Empress's bust on a crescent.

The debasement went on till the time of Diocletian, who in A.D. 296 made a clean sweep of all existing coinage, and issued a fresh series:—an *aureus* of $\frac{1}{60}$ of a pound, and a silver *centenionalis*. The debasement of silver had driven the copper coins out of existence; Diocletian now issued two kinds of copper coins, the *follis* and the *copper denarius*. Of later changes we need only note that Constantine reduced the *aureus* to $\frac{1}{72}$ of a pound, calling it the *solidus* (Fig. 22), and issued two kinds of silver, the *miliarensis* ($= \frac{1}{12}$ *solidus*), and its half, the *siliqua*.

We may now pass to the consideration of the types which occur on the coinage of which we have sketched the history, and of its artistic value. The latter is, at most periods, comparatively small; for the Romans were not an artistic people. Indeed, the hard matter-of-fact way of looking at life, which was characteristic of this race, made it at the same time especially fitted to attain the dominion of the world, and unfitted to entertain the artistic ideals of the Greeks. In one form of art they did attain a very high degree of excellence—and that is, portraiture. But this is precisely the branch of art into which the ideal element least enters. Even so, it was long before the Romans found, so to speak, their artistic vocation. The types of the early coins are such as we might expect from our study of the Greek series: animal-types, such as the ox (possibly a reminiscence of the old medium of exchange, Fig. A), or the elephant (an allusion to the animals employed by the Greek King Pyrrhus, in his war against the Romans in the early years of the third century); or, again, types with a religious significance, such as the eagle standing on a thunderbolt (both attributes of Jupiter). It is not certain which of these early pieces are to be given to Rome and which to other cities of Italy, except in the cases where the word ROMANOM actually occurs on the coin. The *aes grave* series (Figs. B and 1 *ff*) presents us with a somewhat uninteresting set of types. The type of the reverses of all the denominations is uniformly the prow of a vessel of the kind used in the fourth century—a proof, if needed, that these coins did not come in before that time. The various denominations are distinguished, in the first place, by the marks of value (sometimes on both sides) we have already described, and in the second by the type of the obverse. The *as* (Fig. B) bears always the double-head of the god Janus (cp. Fig. 6); the *semis* the laureate head of Jupiter, the *triens* that of Minerva wearing the helmet, the *quadrans* that of Hercules in the lion's skin, the *sextans* that of Mercury in his winged hat (Figs. 1—5), and the *uncia* that of Minerva or Roma herself. These coins are of a style which belongs not to the primitive artist, but rather to a people who care little for the artistic value of the things they handle. The Republican Roman, in fact, cared no more for the beauty of his coins than does the modern Englishman.

The first gold and silver coinage (Figs. 6 and 7) struck, as we have seen, for use outside Rome, bears, like some of the *aes signatum*, the name of the Roman people. As a rule, the types are not of sufficient interest to detain us, since we have seen better things of the same kind done by the Greeks. Fig. 6 shows two soldiers taking an oath over a slain pig. It is interesting to note on No. 7 an early, if not the earliest representation of the Roman national legend, a she-wolf suckling the twins Romulus and Remus.

After the reduction of the *as*, the copper as well as the silver, now actually issued in Rome, bore the name of the city. The most frequent type of the reverse (the obverse bearing the head of Rome) on this early silver is the heavenly twins Castor and Pollux, whose appearance at the battle of Lake Regillus was one of the most popular of Roman legends. The heroes are represented (Fig. 9) on horseback, charging the enemy; they wear conical caps, and above the head of each is a star.

The second and first centuries before Christ form the last period of republican coinage. The characteristic of this time is the appearance on the coins of the names (at first in abbreviated form, and then gradually at greater length) of the officials charged with the issue of money. These names (which, however, cease about 36 B.C.) enable us to ascertain with comparative exactitude the dates at which individual pieces were issued. The types, at first uniform, first began to be varied in 100 B.C., and from this time they have a personal significance; that is to say, they relate to events in which the ancestors of the moneyers, less frequently the moneyers themselves, took, or were supposed to have taken, a part. Thus a denarius, struck between 134 and 114 B.C. by Marcus Cæcilius Metellus (Fig. 11), shows on the reverse a Macedonian shield, with an elephant's head in the centre, the whole surrounded by a laurel wreath. This is, in the first place,

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DAR. PHO. E.Y.G. C°

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an allusion to victories won by Lucius Cæcilius Metellus in Sicily in 250 B.C. Elephants were a formidable feature of the army of the Carthaginian Hasdrubal, whom Metellus defeated at Panormos (Palermo), and the captured animals figure on the coins of his descendant, as they had figured in his own triumphal procession. The shield, on the other hand, must refer to the victories won by another Cæcilius Metellus in Macedonia from 148-146 B.C. These "family" denarii were imitated by the Italian generals who headed the revolt against Rome, known as the Social War of 91-88. The obverse of Fig. 13 bears a head resembling that of Roma on Fig. 9, but with the legend ITALIA. On the reverse of another coin (Fig. 14) are a bull trampling on the Roman she-wolf, and the name of the general Gaius Papius (in the local alphabet). The later denarii of this period bear the name not only of the moneyer but of his superior officer. Thus a coin (Fig. 12) probably struck in Macedonia under Brutus, the murderer of Cæsar, bears on the obverse the name of his subordinate Lucius Sestius and the head of Liberty, on the reverse the name of Brutus himself and sacrificial instruments. The improved style of this period is partly due to the fact that many of the pieces were struck in Greece and the dies engraved, in all probability, by Greek artists. Rome could no longer resist the influence of Greek art, and with the commencement of the Empire there was a great influx of Greek workmen into Rome. Now begins a splendid series of coins with unsurpassable portraits of the rulers of the world (Figs. 16, Augustus; 17, Vespasian; 18, Faustina II.; 24, Trajan, *reverse*, the Forum; 25, Hadrian, *reverse*, Justice). For about two hundred and fifty years the art of portraiture maintains a high level, rising perhaps highest in the time of Hadrian (Fig. 25, *reverse*, Justice) and his immediate successors. The reverse types are often of great interest. No. 27 gives a view of the Coliseum; No. 28 shows Judæa seated under a palm and guarded by a Roman soldier (referring to the subjugation of the Jews by Titus). The increased diameter of the copper and brass coinage reintroduced by Augustus provided room for an art which is almost medallic. What are called Roman medallions (Fig. 26, Marcus Aurelius, *reverse*, Neptune), were pieces of an even larger size, struck in all three metals, and probably serving for memorials and not for currency.

Augustus had abolished the Board of Moneyers in B.C. 3. The right of coinage in gold and silver now resided in the Emperor, whose portrait and title appeared on the obverse of the coins. The details given in the titles often enable us to date a coin more or less accurately. Thus No. 24 was struck, not before the fifth consulship of Trajan (A.D. 103), but before A.D. 112, when he was consul for the sixth time. After the third century, however, the titles cease to be given in full. As regards the bronze coinage of the second or provincial class, it is to be noted that the cities struck large numbers of coins without the head of the Emperor, but with some ideal type, most frequently the head of the Roman Senate, of their own town council, or of the "People." The reverses of the coins were occupied by a great variety of designs, allegorical, mythological, historical, architectural, or merely ornamental. The interpretation of these designs in the case of the Greek provincial coins is most important as illustrating the life of the time. A vast mass of information of historical importance, relating to the religion, politics, and external aspect of the Greek cities, is being gradually gathered from this interesting, though not very artistic series.

We may notice here four coins. The first (No. 29) was struck at Ephesus, and represents the cultus-statue of Diana of the Ephesians in her temple. The idol is mummy-shaped up to the breast, and wears on her head a tall head-dress, from which falls a veil. Her arms stick out sideways from the elbows, and from the hands hang fillets. The lower parts of the columns of the temple were decorated with sculptures in relief, traces of which may be perceived. In the gable we also see a representation of the pedimental sculptures of the temple. No. 30 was struck at Cnidus in Caria, a town adorned by a famous statue by Praxiteles of Aphrodite going down into the bath. The work of the coin is very poor, but is valuable, in connection with the known Roman copies of the statue in Rome and Munich, as giving the pose of the lost original. No. 31 (struck at Elis) represents the famous statue of Zeus at Olympia, by Pheidias. He is seated on his throne, bearing on his right hand a statue of Victory, and holding his sceptre in his left. Finally, No. 32, of Samos, shows us the goddess Hera, in a guise not quite so hieratic as the Ephesian Diana, but still formal. Beside her stands the goddess Nemesis. These coins, though we cannot here discuss their types in greater detail, suffice to show the interest attaching to the class.

After the second century all pretence to artistic merit on the part of Roman coins vanishes. We have space here for only three coins of this later period; No. 21, of Allectus, the usurper who reigned in Britain from 293 to 296 A.D. (*reverse*, figure of Peace, carrying flower and sceptre); No. 22 of Constantine the Great (*reverse*, Victory carrying a trophy and palm branch; in the field the Christian monogram); No. 23, a *triens* ($\frac{1}{3}$ solidus) of Romulus Augustus, the last Emperor of Rome (475-6 A.D.). This last coin bears the simple cross; but the solidus of Constantine shows the Christian monogram in combination with the distinctly pagan type of Victory, illustrating the fact that the transition from paganism was not a complete and sudden change, but a gradual grafting of the new ideas on the old stock.

NOTE.—The various metals are distinguished in the plate as follows:—AV, Aurum, gold; AR, Argentum, silver; Æ, Aes, bronze or copper.

ALABASTER.

By RICHARD BEYNON.

ALABASTER does not hold a very high place in popular taste at the present day. It is admittedly a delicate and pretty stone; but that is all. Time was, however, when its translucent beauties were universally admired, and the "whitish stone," as the Arabic *al batstraton* denominates it, was keenly sought after. The alabaster so highly prized by the ancient inhabitants of the Nile valley does not seem to have been a true alabaster at all, but rather a species of stalagmitic limestone, beautifully clouded and prettily banded, and now generally known as Oriental alabaster, or onyx marble. Alabaster boxes or bottles were considered the most fitting receptacles for the costliest of Eastern drugs and perfumed ointments. In fact, the term *alabastra* came to be applied to any valuable vessel in which the rarer perfumes were contained.

Among the Romans alabaster was as highly esteemed as among the Egyptians. They looked upon the chaste purity of the white variety as peculiarly fitting it to contain the ashes of the dead, and hence the fact that the cinerary urns were so largely constructed out of this material. But the Romans were specially favoured in the matter of alabaster. In the province of Pisa are deposits of the mineral, which were doubtless being worked upwards of four thousand years ago. The true alabaster, the hydrated gypsum, or sulphate of lime, is found in

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large quantities nowhere outside the province of Pisa. Of so-called alabasters there are legion. They occur in the Tyrol, in Saxony, in Derbyshire, and many other places; but most of them, like the Oriental alabaster, are a form of carbonate of lime. Even where the alabaster is alabaster, it is frequently so poor in quality and so lacking in beauty and fineness of texture, that it is subjected to the base process of being ground to a powder to make the well-known plaster of Paris. But the Pisan alabasters are simply incomparable. All possess a marvellous softness of texture, and some can even be scratched with the finger-nail. But the rarest and most expensive of all alabasters is a yellow one found at Volterra. This city has been famous for its alabaster from time immemorial.

Four thousand years ago its alabaster quarries, if they can be so described, were in full swing, and they have probably been worked continuously ever since. The Palazzo Pubblico of this ancient Etruscan city contains a museum rich in priceless antiquities, among which cinerary urns of alabaster play a prominent part. In the days of the Etruscan league when Volterra was a city of much importance, with a population numbering one hundred and twenty thousand, its walls, forty feet high and thirteen feet thick, enclosed a space four and a half miles in circumference. Beyond the crumbling ruins of this mighty barrier lie the alabaster caverns. Quarries they cannot be called, for the mineral is not extricated in the open, but dug out of caves, the entrance to which is often by way of a long and winding passage. No shafts are sunk from the outer air, so that the ventilation is none of the best, and the atmosphere is hot and stifling, as may be readily understood when it is stated that some of the caves are reached by subterranean passages a mile in length. This necessitates the quarry men working in short shifts of two hours, and no underground workman is allowed to labour more than six hours per day. In spite of this, however, alabaster getting is held to be healthy work, the white impalpable dust which each worker must inhale in large quantities, being considered antidotal to the diseases common to the district. Be that as it may, the alabaster workers are certainly as healthy and long-lived as their comrades who labour in the open.

The alabaster is found in nodules or detached blocks imbedded in clay or limestone, and great care has to be taken in extricating these so as not to reduce the size of the piece.

The freshly-wrought alabaster is either exported or disposed of to the carvers or sculptors, or to the proprietors of fine art galleries who engage sculptors to carve statuary, flowers, etc. Many carvers, however, prefer to work for their own hand and buy their alabaster direct from the owners of the mines, trusting to sell their finished work to customers direct, or failing this to the middlemen who own the galleries. Much of the raw material, however, is not worked up at Volterra but is sent off to Florence, Leghorn, or Pisa, where there is a better chance of obtaining patrons.

At first sight it seems difficult to account for the declining character of the alabaster industry. But one cause which has operated in this direction is the poor taste displayed by the carvers and sculptors of alabaster articles. The artistic instincts of both English and Americans have of late years undergone a very material refining process, and what years ago might have been dubbed elegant and pretty, would, according to our better lights, be considered as a grave offence against the canons of correct taste. Everyone is familiar with the wonderfully-carved alabaster flowers, or fruit, or florid vases which our sea-going friends insist we shall religiously preserve under a glass case as a treasured possession. These are bad enough in all conscience; but what can be said of alabaster models of steamships carefully and elaborately carved in full detail, even to the propeller, the whole supported upon pediments of alabaster as a ship rests upon the blocks when in graving dock? For our American friends there are statues of Liberty, Brooklyn suspension bridges, New York hotels with real windows of coloured glass, through which the light of diminutive candles may shine. All these, it must be admitted, are most faithfully executed, but of artistic feeling there is little or none. Italian carvers, too, seem to think that nothing is so pretty and effective as an alabaster picture-frame!

The English climate, too, is all against alabaster. To a certain extent the substance is soluble in water, and the humidity of our atmosphere soon creates a roughness of surface, which has a powerful affinity for dust and grime. A leaning Tower of Pisa in alabaster may be wonderfully pretty, but to preserve the beautiful translucency it is necessary to encase it, and the English nation has now been educated above the once omnipresent glass shade. Clearly, the alabaster industry is at present under a cloud, which shows little evidence of lifting. It may, however, alter for the better when the artistic taste of the Italian carvers improves, and they set themselves to reproduce in miniature the truly beautiful works of art with which their land abounds.

ADHESIVE ORGANS IN ANIMALS.

By R. LYDEKKER, B.A.Cantab., F.R.S.

EITHER for the purpose of holding on to inanimate substances, and thus securing protection from attack or safety from the buffetings of the waves, or by attaching themselves to the bodies of other creatures, and thus obtaining an ample supply of food without any exertions of their own, a considerable number of animals have developed suckers, or other adhesive organs, on some parts of their bodies or limbs, and as these sucking-organs vary considerably in their specialization and plan of structure in different groups, their comparison forms an interesting subject of study. In addition to these sucking-discs, which are purely for the purpose of adhesion, there are in certain animals, such as the lampreys and leeches, suckers formed by the mouth, thus enabling the fortunate owners of such organs not only to attach themselves, but likewise to procure their food by devouring the blood or flesh of the animal to which they are temporarily fastened.

Probably the simplest, although nevertheless a highly efficient, type of sucker are those of the limpet, and of certain other molluscs found on some parts of our coasts and known as chitons. In these creatures the sucker is simply the soft under surface of the body—the so-called foot—which on being applied to any fairly smooth surface, and the centre elevated by muscular action, at once forms a sucking organ without any special structural modification. And it is probable that in a considerable number of instances suckers have originated from a portion of the general surface of the body having been used in this manner, and finally developing structural modification. Suckers, as everybody knows, are very commonly present in insects, but are much more rare among the higher animals and molluscs, and it is therefore chiefly from the two latter groups that our examples of these peculiar structures will be drawn.

Among mammals, suctorial discs are a very unusual

feature. It is true that there are so-called blood-sucking bats, but these merely abrade the skin with their sharp front teeth and swallow the blood as it flows from the wound, without having the mouth modified for sucking. It is, however, in the same group that the best developed suckers found in the whole mammalian class occur. These suckers take the form of perfect adhesive discs developed on the wings at the base of the claw, and also on the soles of the hind foot, the wing-discs being very much larger than those on the hind foot. Curiously enough these suckers occur only in two species of bats, one of which (*Thyraptera*) inhabits Brazil, and the other (*Myxopoda*) the island of Madagascar; the distribution of these two species being one out of several instances of a community between the faunas of Madagascar and South America. In the Brazilian species the clinging organs take the form of small, circular, stalked, hollow discs closely resembling in miniature those of cuttlefishes. On the other hand, in the Malagasy bat the wing-organ is a large, sessile, horseshoe-like adhesive pad, covering the whole of the lower surface of the thumb, and having its circular margin directed forwards. In both cases the sucker on the hind foot is a miniature of that on the wing. By the aid of their adhesive organs these bats are enabled to cling to perfectly smooth vertical surfaces, in the same manner as a fly hangs on to a window-pane.

Apparently the only other mammal furnished with suckers is a peculiar kind of web-footed water-shrew (*Nectogale elegans*) from Tibet, in which the soles of the feet bear disc-like adhesive pads, by means of which the creature is believed to hold on to smooth rocks and stones in the beds of the rapid streams it frequents.

Among reptiles, many of the lizards belonging to the family of geekos have the extremities of their toes dilated into adhesive pads, by which they are enabled to cling to

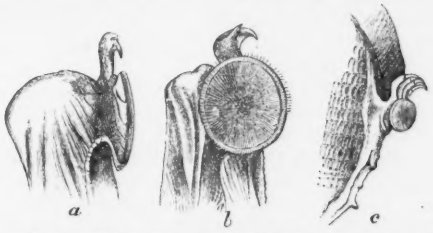

Fig. 1.—Adhesive Discs of Sucker-footed Bat. *a*, *b*, disc of wing; *c*, that of hind foot.

the surface of walls or upright faces of rocks. These do not, however, take the form of true suckers, but are marked by a number of very fine plates, or lamellæ, placed symmetrically to one another, but differing very markedly in their mode of arrangement in the various genera. This type of adhesive organ seems to foreshadow that of the remora among the fishes. In the amphibian class a different type of adhesive organ is displayed by many frogs, not only in the elegant little tree-frogs (*Hylidæ*), but likewise in some of the true frogs (*Ranidæ*). In these animals the extremities of the toes are dilated into soft, rounded pads, furnished with a viscid secretion, while there are frequently similar pads on the under surface of the joints of the toes. Although the sticky secretion doubtless plays an important part in rendering these discs adhesive, it is not improbable that they also act to a certain extent as true suckers.

Greater variety obtains in the adhesive organs of fishes. Perhaps the simplest type is that of the familiar little gobies (*Gobiidæ*) of our seaside rock-pools, in which the pelvic or hinder pair of fins are united together in the middle line so as to form a circular, funnel-shaped cavity, apparently acting as an adhesive organ, by means of which these fish anchor themselves to rocks or sea-weed. In the true gobies (*Gobius*) the disc thus formed is separate from the surface of the body, to which, however, it becomes attached in the members of the allied tropical genus *Sicydium*. Although formed in the same manner by the union of the pelvic fins to form its bony base, the adhesive organ of the much larger British fishes known as lump-

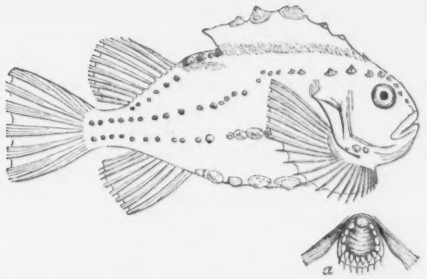

Fig. 2.—The Lump-sucker and its Adhesive Disc (*a*).

suckers (*Cyclopterus*) attains a considerably higher degree of development. Here it forms a circular disc placed close under the chin, and surrounded by a fringe of filaments; and so well does this sucker act that, when once attached, it is exceedingly difficult to make one of these fish let go its hold. In a fish of eleven and a half pounds, the disc measured upwards of two and three-quarter inches in diameter, and Frank Buckland states that even after death its adhesive powers were retained; "for," he writes, "after casting the fish, and having cut out the sucker, leaving the thick side-bones under the gills, as it were for handles, and having wetted the window-sill, I placed the sucker flat on it, and it was just as much as I could do to pull it off vertically, but there was not the slightest resistance to any side-movement."

The most extraordinary adhesive organ is, however, that of the far-famed sucking-fishes, or remoræ (*Echeneis*), of which there are about half-a-score species, some of which may attain a couple of feet in length. In these fishes the organ takes the form of a flat, oval disc, covering the upper surface of the head and neck, divided into a number of chambers by a middle longitudinal ridge, and a series of pairs of transverse partitions, varying in number from twelve to twenty-seven. The disc causes the upper portion of the head to be so flattened that, when the fish is placed in the ordinary position, it looks as though it were upside down; the illusion being intensified by the circumstance that generally the lower surface of the body is darker than the upper. Unlike what obtains in the fishes noticed above, in the remora the adhesive disc is formed out of the spinous or front portion of the back-fin, which has completely lost its original character. Regarding its origin, Dr. Günther writes that the spines of the fin "being composed of two halves, each half is bent down towards the right and the left, forming a support to a double series of tranverse lamellæ, rough on their edges, the whole disc being of an oval shape, and surrounded by a membranous fringe. Each pair of lamellæ is formed out of one spine, which, as usual, is supported at the base by an interneural spine." When the remora applies the disc to any flat surface, such as the skin of a shark, the shell of a turtle, or a ship's bottom, the plates, which are usually depressed, are raised, and a series of vacua produced, and by this means the creature adheres so tightly that it can scarcely be detached except by pushing or

pulling it along the surface. Many fables have collected round the remora, which was known to Aristotle, and in Ovid's time it was believed to have the power of stopping a vessel on its course; although, how this was effected the poet is careful not to say. The dark coloration of the lower parts is due to the circumstance that, when attached to a foreign body, the fish generally have this surface turned upwards. It has indeed been suggested that the fish habitually swims, even when detached, in the reversed position, but this has not been confirmed.

By being carried about, the remora, of course, gets a much better chance of obtaining food than would be the case if it had to depend upon its own powers of locomotion; but according to the observations of F. D. Bennett, the duration of the fish's adherence to foreign bodies is much less than commonly supposed. Thus he writes that "it often merely swims around the body it attends, and only fixes upon it occasionally, and for a very short time. The adhesion of the buckler is chiefly effected by the smooth membrane that margins it. After the death of the fish, and even after the head has been separated from the body, the moist membranous border of this organ adheres to a plain surface with undiminished power. One muscle can be raised and depressed by the fish independently of the others, or all can be moved simultaneously and rapidly. Their uses are, to fix the sucker more firmly, to offer resistance in one determinate direction, and probably to liberate the sucker by relieving the vacuum."

Not the least curious feature connected with the remora is that it is a member of a family of which the other representatives have no adhesive disc; and it has a very near ally in a fish from the warmer coasts of the Atlantic and Indian Oceans, known as *Elacate nigra*. Hence the development of the suctorial disc is a peculiar and specialized feature which has not been inherited from other genera. That the evolution took place at an epoch comparatively remote is, however, proved by the occurrence of a fossil sucking-fish in the lower Eocene slate of Glarus, in Switzerland.

To find an adhesive organ comparable to that of the sucker-footed bats, we have to go to the molluscs, where the cuttlefish and squids have these organs developed in great numbers on the tentacles, or so-called arms, surrounding the head. In most cases these are arranged on the non-pedunculate arms in rows (usually four or two), becoming smaller and more numerous towards the tip of the arms; and whereas in some forms their base is flush with the surface of the latter, in others they are raised on short stalks. Then again, their margins may be strengthened by a horny rim, either smooth or crenulated; and sometimes their centre is armed with a strong hook, which can be protruded or retracted like the claw of a cat. Structurally, according to the description of Owen, these discs have a slightly swollen margin, from which a series of muscular folds converge towards the centre, where a circular aperture conducts to a cavity of gradually increasing width. Within this chamber is a kind of button, which can be elevated or depressed in the same manner as the piston of a syringe, so that when the sucker is applied and the piston withdrawn, a vacuum is immediately created.

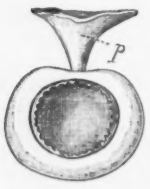

Fig. 3—Sucker of Cuttle-Fish.

It would be very interesting if we could trace the gradual evolution of these highly specialized organs, but this is unfortunately impossible. They may, however, have arisen after cuttlefish were evolved as a distinct group, since they are unknown in the allied group of cephalopods to which the nautilus belongs; but they are now constant throughout the group, and thus differ markedly from all the sucking organs hitherto mentioned. In the gigantic cuttles occasionally met with in the ocean, they attain an enormous size, being, it is said, in some cases, of the size of dinner-plates. While these suckers are employed to anchor their owners to submarine rocks, they are likewise used for the purpose of seizing prey and bringing it within reach of the jaws, and in this latter respect differ from all those hitherto noticed.

Among insects, as already mentioned, many exquisite examples of adhesive organs are to be met with, but the only ones we have space to refer to here are those on the fore-legs of the males of many of the water-beetles of the family *Dyticidæ*. In the common English *Dyticus* the first joints of the tarsus are widely expanded so as to form a nearly circular plate; this being provided with a number of suckers, one of which forms a very large disc, furnished with strong radiating fibre, while a second and smaller one is of the same type. Besides these are a number of small tubular and somewhat club-shaped bodies, each furnished with a very delicate sucker at its extremity. We have been unable to come across any account of the use to which these very beautiful examples of adhesive organs are applied, but their occurrence in the male sex alone may suggest one to our readers.

In all the foregoing instances the adhesive organs are formed either on the body or limbs, and, with the exception of the cuttles, are used solely as a means of attachment. The lampreys (*Petromyzidæ*) and leeches (*Hirudinidæ*), which will be our last examples of these curious structures, afford, on the other hand, instances where the mouth is modified into an adhesive organ. In the lampreys, which although formerly included among fishes, are now generally regarded as constituting a class by themselves, the mouth is surrounded by a continuous circular or suboval sucking lip, while internally it is armed with a variable number of sharp teeth resting on a soft cushion. Lampreys feed on the flesh of fishes, to whose bodies they attach themselves by means of the suctorial mouth, and when thus firmly fixed, rasp away the flesh with their teeth. Frequently they cling for a long time to the surface of their victims, and are thus carried long distances. The occurrence of fossil lampreys in the older Palæozoic rocks of Scotland proves that this type of sucking mouth is at least a very ancient, and probably a primitive one.

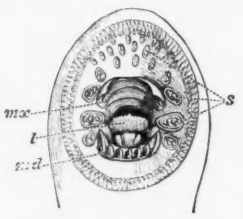

Fig. 4.—Sucking-mouth of Lamprey.

Most likely the same is the case with the leeches, which, as our readers are doubtless aware, belong to the great group of annelids, or worms. In these, the anterior end of the body terminates in a large circular sucker, within which, or the pharynx, is the mouth. Very generally, as in the common medicinal leech, the mouth is armed with sharp teeth, and thus presents a curious structural similarity to that of the lampreys, although there is, of course, no genetic connection between the two groups. Many leeches also have a sucker at the opposite extremity of the body, by which they are in the habit of attaching themselves to the leaves of trees, from which basis they extend their bodies in the hope of catching hold of a passing animal. In their habits leeches also present a curious similarity to lampreys, except that they only suck the blood of their victims, instead of feeding on the flesh.

Did space permit, many more examples of adhesive organs might be noticed, although the majority of the most striking have been referred to. While adhesive mouths appear to be primitive features of the groups in which they occur, other sucking-organs, with the probable exception of those of the cuttlefishes, seem to be comparatively late developments, and occur only among certain members of the groups in which they are found at all. All these appear to have been produced quite independently in the various groups, and as a sucker is not capable of indefinite variation in form, it is not to be wondered at that structure found in one group is frequently paralleled in a totally different group. We have, therefore, in these organs another excellent example of that parallelism in development to which reference has been so often made in former articles in KNOWLEDGE.

NOTE.—Figure 1 is taken from the "Study of Mammals" by Sir William Flower and R. Lydekker, and Figures 2 and 4 from the "Study of Fishes" by Dr. Günther, by courtesy of Messrs. Black. Figure 3 is taken from Cooke's "Molluscs," by courtesy of Messrs. Macmillan.

SPECTRUM ANALYSIS.—II.

By J. J. STEWART, B.A.Cantab., B.Sc.Lond.

BESIDES the method of obtaining a spectrum of a source of light described in a former article,* that is, by means of refraction through a prism, there is another method of great importance which in some respects is preferable to that of the ordinary one in which the prism is used, and this is the method of the diffraction grating. This method is not only of great use in spectrum analysis, but is also valuable as being the most accurate process for measuring the wave-length of light.

The phenomenon known as diffraction is an example of the ability of light to bend round corners or sharp edges. Light, as is well known, is propagated in straight lines, and when it passes through an opening in a shutter and falls on a screen a bright patch of light is seen on the screen surrounded by a dark shadow; the illuminated area being bounded by a line or set of lines, which are obtained by drawing straight lines from the boundary of the opening to the boundary of the area lit up on the screen. The sharply defined shadows cast by objects placed in direct sunlight also indicate to everyone the fact of the rectilinear propagation of light, and it is this rectilinear propagation which formed the first great difficulty in the way of the acceptance of the undulatory theory of light. This difficulty has been completely got over, and the propagation in straight lines has been explained by means of the wave theory.

When we come to consider the phenomena of diffraction, we have before us a set of facts which cannot be accounted for by the old emission hypothesis of Newton, but have been shown to follow naturally from the undulatory theory of light. What these diffraction phenomena are I will now shortly state.

When light is allowed to pass through a small opening —for example, a narrow slit with a lamp flame behind it— a bright area is seen on a screen in front of the slit corresponding in shape to the form of the slit. This bright area is surrounded by the darkness of the shadow, and, roughly speaking, the illuminated area consists of all those portions of the screen to which straight lines can be drawn from the source of light through the slit. But if the slit be a narrow one, and we observe the effect on the screen closely, it is seen that the shadow is not sharply defined; darkness does not commence at once at the edge of the bright area, but a system of fringes is produced, coloured bands are seen, and a succession of brighter and darker areas parallel to the length of the opening through which the light comes. If the light we use is of one colour only— if, for example, it passes through a piece of red glass before it falls on the slit—a series of bright red bands alternating with dark and completely black ones is noticed. The distance apart of the bands depends partly on the width of the slit and its distance from the screen, and they become obliterated and fade into uniform darkness at a short distance from the bright central area. If the distance between the slit and the screen is not too great, another set of fringes can be seen inside the bright area which is the projection of the opening on the screen.

Similar effects are obtained when light is obstructed by an opaque obstacle of narrow width, or when it passes by the sharply-defined straight edge of some obstacle. It was in this form that the phenomenon seems to have been first observed about the middle of the seventeenth century, by Grimaldi, but the explanation was not known till considerably later. He allowed light to pass into a darkened room through a very small round opening, and on placing a small opaque obstacle in the path of the cone of light thus produced, he noticed that its shadow on a screen was much larger than its geometrical projection. This showed that the path of the light was not altogether a straight line, but that it was bent out of its rectilinear course owing to the presence of the obstacle. The shadows he observed to be bordered by three rainbow-coloured bands, the direction of which was parallel to the edge of the shadow, while their intensity fell off as they became more distant from the edge. Newton also noticed these effects, and he let light pass through the narrow opening between two knife edges, getting an image on a screen which was bordered by three bright bands which were violet nearest the shadow and red farthest away from it.

These remarkable appearances are readily produced, and can be seen by anyone who places a narrow slit cut in a piece of cardboard near a candle flame, and then views it at the distance of a few feet through another slit held parallel to the first and close to the eye. The appearance of the first slit as thus seen will be that of a bright band of light surrounded on each side by a set of parallel bands of alternate light and darkness, the brighter parts being of various colours.

In order to produce a spectrum by means of diffraction a "grating" is used. This consists of a number of parallel lines ruled on a glass plate, at equal distances apart, by means of a diamond point. Light falling on such a plate is reflected at the lines, but passes freely through the spaces between. The diffraction grating has thus the same effect as a system of fine opaque threads alternating with clear spaces. We may also consider it as an arrangement of numerous slits very close together. Gratings thus constructed often contain from twenty thousand to forty thousand lines to the inch, and the rulings can only be seen when the grating is looked at through a powerful microscope. Diffraction spectra can also be produced by placing a piece of fine wire gauze in the course of the light, the opaque wires taking the place of the rulings; but with a coarse arrangement like this the spectra are not nearly so good, the dispersion and the purity being less. The production of a good grating is a matter of great difficulty. The diamond point is apt to break, and it is not easy to make the rulings at equal distances throughout the whole grating; errors through variation in the spacing would cause irregularities in the spectra

* *See* KNOWLEDGE, July, 1895.

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and inaccuracies in the measurements of wave-length, etc. Even with an ordinary wire grating, however, not at all a perfect instrument, Fraunhofer in his early operations on the solar spectrum obtained wonderfully accurate measurements.

In order to explain how a spectrum can be formed by means of a diffraction grating, let us first consider the phenomenon known as the interference of light, on which the effect largely depends. If a light substance, such as a piece of cork, was floating in water while a series of waves was passing along, the cork would be observed to move up and down nearly in a vertical line. The motion of the water particles is like that of the cork, they move up and down in straight lines. Now if instead of one set of waves we had two, matters might be so arranged that the crests of one set of waves fell on the hollows of the other set; when this took place we should have what is called interference of the waves. The water surface, when this interference took place, would not be disturbed if the two wave-systems were of equal magnitude; no waves would be seen; and the cork would be at rest on the surface. One wave-system would urge it upwards and the other downwards, and these forces on it would just balance each other when the two wave-systems were present. Interference also occurs when the crests of one system of waves fall on the crests of another; the amplitude of the wave disturbance is increased, that is, the distance from the bottom of the trough to the top of the crest is made greater.

In the case of the grating, the diffraction and interference of light produce effects which resemble those of refraction in the case of the prism. To explain how this occurs let us refer to the diagram, in which A B C D represent four openings in a grating, or four clear spaces between the rulings. Let us suppose the front of the advancing light-wave is parallel to the grating, and that the diagram represents a section through the grating at right angles to the plane of the grating; then we may consider A B C and D to be four points at equal distances apart, emitting light of the same wave-length, the vibrations being such that a crest starts from each of the points A B C D at the same time. Consider the light which travels from A B C D in the direction D L, and let a lens L be interposed in its path. Draw lines D M, C N, B P, at right angles to the direction D L of the light. These lines will cut off lengths K C, R Q, Q B, M N, N P, P A from the lines D L, etc., representing the rays, and these lengths are from the geometry of the figure all equal. If the lengths A P, P N, etc., be taken to be the magnification of a wave-length of light, when a crest of a wave is at A crests will also be at P, N, and M, and midway between these points will be the troughs of the waves. Similarly, at the same moment, crests will occupy the positions Q, R, and K. The vibrations, then, are in the same phase along the line D K R M, crests at the same instant being at D, K, etc. The interposition of the lens L causes the rays to come to a point at F, the focus of the lens, and the time taken by the light to travel from D, K, R, and M to F is the same; therefore, the waves being in the same phase along the line D M, they will be in the same phase at F—that is, the crests will all coincide at F, and that point will be brightly lit up. Light of a different wave-length will be brought to a focus different from F, but near to it, and the effect will be that of a number of points or lines, each consisting of illumination of a different wave-length and different colour placed close together—that is, a spectrum is formed. Taking a similar figure in which the distances C K, Q R, etc., represent half wave-lengths, when a crest is at A a trough of a wave will be at P, another crest at N, and so on; and when a crest is situated at D a trough will be passing over K, a crest over R, and another trough over M. Thus at F crests and hollows will be brought together in equal number, and the result will be absence of illumination at that point—F will be dark. The position of F for light of a certain wave-length will depend on the magnitude of that wave-length; for light of a slightly differing wave-length, F will be situated at another point, but close to the first. Thus, considering A, B, C and D a section through a grating, the effect on a screen passing through F, or the appearance to an eye looking through a telescope of which L is the object-glass, will be that of a band of light, each line in which is produced by light of different wave-length, and therefore of differing colour, these lines being distinct and not overlapping. This result is expressed by saying that a pure spectrum is produced. A pure spectrum is one in which overlapping of light of different wave-length and colour does not take place.

A great advantage which a spectrum formed by a grating has over that given by a prism proceeds from the fact that the dispersion depends only on the wave-length and the closeness of the rulings. Thus any one diffraction spectrum is an exact copy of any other on a larger or smaller scale. The ratio of the widths occupied in the spectrum by any two colours is the same in all diffraction spectra. This does not hold in the case of the spectra formed by prisms. The relative dispersion in spreading out of the colours differs with different prisms according to the kinds of glass of which they are made. Thus prism spectra cannot be compared together, but observations with a grating can be compared with others wherever taken and with whatever instrument. On this account the diffraction spectrum is chosen as the standard.

(To be continued.)

Science Notes.

The following interesting results of experiments relating to the growth of trees at different times of the day have been sent to us by Mr. E. H. Thompson, the Government entomologist of Tasmania. Measurements were taken as far as possible every three hours, with the following results:—

From 6 a.m. to 9 a m	... ...	8¾ per cent. of growth
,, 9 a.m. to noon	... ...	1½ ,, ,,
,, noon to 3 p m.	... ...	No growth
,, 3 p.m. to 6 p.m.	... ...	,,
,, 6 p.m. to 9 p.m.	... ...	1½ per cent. of growth
,, 9 p.m. to 12 p.m.	... ...	3⅞ ,, ,,
,, 12 p.m. to 6 a.m.	... ...	85 ,, ,,

The greatest growths in twenty-four hours were banksia rose, six and a half inches; geranium, five and three-quarter inches; wattle, four and one-third inches; apple, two and a quarter inches; pear, one and a third inches.

Writing from Lippentott, Manitoba, Mr. Arthur Parry says that the sun pillar, described by Mr. Barber in the June number of Knowledge, has been more than once visible there during the past winter, while on Jan. 10th and 30th a similar shaft was visible proceeding from the moon. With regard to two other phenomena which Mr. Parry would like explained, he writes, on Jan. 12th, a "circle round the moon, with curious shaft of light obliquely across it, visible at 11 p.m. for a short time"; and on March 9th, "bright moondogs and circle above. The peculiarity of which lies in the fact that the circle which should have connected the moondogs was not visible, while the circle which had no visible connection with them was bright and complete."

Dr. Janssen has recently made an ascent to the observatory on Mont Blanc, his object being to satisfy himself concerning the safety of the new telescope which has been conveyed to the observatory, and to inspect the meteorograph which had ceased to be in working order. He took the opportunity of observing the aqueous bands in the solar spectrum. The air above him being very rare and also extremely dry, he found that the bands at C and D were absolutely invisible. Dr. Janssen already considers it certain that there is neither oxygen nor aqueous vapour in the solar envelopes.

Two useful catalogues of scientific magic lantern slides have been sent to us. The one from Messrs. Newton and Co. contains among other things long series of slides on astronomy, human physiology, hop culture, volcanoes, and a new and useful series on British birds taken from Mr. Lodge's drawings in Mr. Hudson's new book on the subject. The other list, from Messrs. York and Son, contains a number of good series on natural philosophy, astronomy, mines, geography, and other subjects.

A Frenchman, Mons. Dubois, has made an interesting suggestion as to the origin of colour-blindness. This defect of vision almost invariably consists in inability to recognize red. Now a body cooling down from incandescence extends its spectrum towards the red end, or in other words the white hot or violet-coloured body becomes yellow and finally a dull red as it cools. A few stars such as Sirius are white hot, many others like our sun are cooler and therefore yellow, whilst others are so cooled down as to shine with a dull red light. Primitive man, according to Mons. Dubois, lived when the sun was in either the Sirius or the pre-Sirius stage, that is, when the sun, which is the source of all colour, was white hot, and had no red component in its spectrum; he had, therefore, no power of recognizing red. Colour-blindness, therefore, says Mons. Dubois, is merely atavism or degeneration to the primitive type. The objection to this ingenious theory is that we have no reason whatever for supposing that primitive man was contemporary with a white hot sun; further, all white hot suns that we know of have some red at any rate in their spectrum. The intensity of particular components of the spectrum may vary, but the components are still there.

The fact that the coming total solar eclipse is visible so near to us as Norway will doubtless induce a number of people to journey there in August, 1896. The Orient Steam Navigation Company have already organized an expedition to Vadsö. One of their steamers is to leave London on July 21st, arriving at Vadsö on August 3rd, and leaving there on the 10th is to be back again in London on August 17th. Intending observers will do well to take advantage of this comparatively inexpensive way of travelling to and from the point of observation.

From observations at various high altitudes made last year, and recently published, it has been found that the quantity of solar radiation transmitted through the atmosphere depends chiefly upon the tension of the aqueous vapour, quite apart from the hygrometric state. On fine days, with the same vapour-tension, the amount of solar radiation transmitted is the same, but the amount decreases rapidly as this tension rises and the amount of vapour increases. With a perfectly clear sky the radiation transmitted is greater when the sky is dark blue than when it is light blue; thus it is important when comparing various observations on the heat from the sun, to determine the colour of the sky by some accurate instrument.

We give our readers an excellent photograph of ribbon lightning, taken by Mr. W. J. Bishop at Bath, on August 22nd, at 1.35 a.m. The irregular jagged course through the air of so-called ribbon lightning is particularly well-marked, one side of the ribbon being much brighter than the other, with a series of brilliant lines running parallel to the bright edge, giving the flash the appearance of varying greatly in vividness. This is much more apparent in the original photograph, the engraving having suffered somewhat in detail by reproduction.

VARIABLE RED STARS.

By Dr. A. BREWSTER, Jun.

THE atmospheres surrounding the glowing interior of red stars contain, according to their spectra, chemical compounds, and are, therefore, relatively cool. If in these atmospheres some vapours are cooled to their dew point, the stars, never ceasing in their loss of heat by radiation, will cause those vapours to condense in obscuring clouds, which will shut off the light of the glowing interior and prepare a minimum without the least change of temperature.

These cool atmospheres, however, do not only contain saturated vapours but also molecules (A and B) of dissociated matter, cooled to a point, where their recombination becomes possible. That recombination is nevertheless impossible so long as the molecules A and B are separated by too great a number of other molecules (R) with which they are mixed. For the same reason the molecules O_2 and H_2 of dissociated water do not recombine when, as Deville has shown, they are mixed with a sufficient quantity of carbonic acid.* Now, as among these admixed molecules R are also those of the saturated vapours indicated here above, it is plain that their condensation into clouds will rapidly diminish their number and cause the remaining molecules R to become finally too few in number to hinder the union of A and B any longer.

Then at once, and as far as possible, these molecules will unite, and the heat then produced will vaporize the clouds of the minimum and restore the maximum by opening again to view the constantly glowing interior of the star.

This rise to maximum, just like the fall to minimum, happens without any change of temperature, for the heat producing it, no matter how great it may be, will be totally

* Debray: Dict. de Chimie, par A. Wurtz, Art. Dissociation, p. 1174. In many other cases a similar influence of admixed molecules R has been observed as, *e.g.*, in a mixture of H_2 and O_2 when exposed to light. The addition of molecules R then strongly diminishes the rapidity of the combination. [Bunsen u. Roscoe: Pogg. Ann. C., p. 43.] The current views as to electrolytical dissociation point also to a similar influence of the water-molecules, preventing, when sufficiently numerous, the separated ions from combining.

absorbed by the vaporization of the obscuring clouds, and, this work ended, the temperature can never be higher than before, since an increase of temperature would cause an increase of dissociation of the molecules A B, while the only source of heat is an increase of their association. The restoration of the maximum being explained in this way, the star's atmosphere is now filled again with the molecules of the vaporized clouds, and the remaining molecules A and B are, as before, prevented from combining. But under the never-ceasing influence of the star's loss of heat by radiation the saturated vapours will condense again in obscuring clouds. The thicker these clouds become, the nearer draws the moment of a new partial combination of A and B, causing a new maximum by a new evaporation of the minimum clouds, and so on.

The more or less simultaneous evaporation of clouds in an entire spherical layer of the star, which my theory demands, would be impossible if the star's atmosphere bore any resemblance to our terrestrial atmosphere, with its irregularly distributed temperature. But since the disturbances of our atmosphere, entirely due to an external cause, viz., our sun (that is, to a cause which is not at work on the stars), there is no reason why all the points of any one spherical layer should not have the same temperature, that temperature being only dependent on the distance from the star's centre. The only cause which would render it otherwise, would be some inequality in cooling and some motion so produced. But, as the star's atmospheres are necessarily rich in dissociated and vaporized matter ready to condense and thus to produce new heat, in proportion as the existing heat is lost by radiation, a sudden fall of temperature is impossible in it. Just as steam in losing heat cannot cool below 100°, as long as the whole mass has not been converted into water, so no incandescent vapour can fall in temperature as long as some of the molecules condensable at this temperature remain uncondensed. Thus, if the gaseous and vaporous mixture, which form the star's atmosphere, has not yet reached this condition, it will preserve its temperature and tranquillity, and we see then no reason why all the points of the same spherical layer should not have the same temperature.

The current ideas of the enormous scale upon which disturbances take place in the solar atmosphere are almost wholly based upon the simplest interpretation of the displacement of lines in prominences, but this interpretation is not necessarily the only possible one. Secchi (Le Soleil II., pp. 112, 124) and Young (The Sun, pp. 165, 164, 241) have often stated that if the displacements did not exist, they would be prepared to consider the prominences as formed where we see them, something like the deposition of dew, or the propagation of a flame along a train of gunpowder. M. Fènyi, when discussing my explanation of the prominences as merely evanescent illuminations caused by the propagation of chemical actions in comparatively tranquil matter (A. and A. 1894, p. 127), urges the same objections, but adds, nevertheless: "We must confess that not only do the enormous velocities observed in these prominences find a welcome explanation in Brester's theory, but that the details of the development and the banded structure are brought into better accord." If it be admitted that in prominences the displacements of their lines do not prove their motions to be real, not only the prominences themselves, but also almost all other solar phenomena, as, for example, the undisturbed stratification of the solar atmosphere, become much more clear. I tried to show this in my theory of the sun.

Recent publications give, I think, the impression that there is a growing suspicion that spectral lines are liable to be displaced by other causes besides those of motion in the line of sight. There is, for instance, the opinion of the late President of the Royal Astronomical Society, Captain W. de W. Abney, who, speaking at a recent meeting of that society, about velocities of one hundred thousand miles a minute in the solar atmosphere, concludes as follows: "Whatever may be the cause of this, I think that we need not come to the definite conclusion that it is absolutely matter which is moving at this surprising velocity, but that the appearance may proceed from other causes. We have learned our lesson from text books where we are told that such and such is the case regarding the prominences and the sun's surface. It remains to be shown whether the text books are right or whether new text books must be written for the rising generation." (*Observatory*, January, 1895.) (See also W. H. Monck, Publications of the Astronomical Society of the Pacific, VII., p. 38.)

My theory so far described, shows that a red variable can be compared to a clock. Chemical combination of dissociated matter, A and B, when cooling, being the clock-spring when running down, and the intermittent evaporation of dark condensed admixed matter R being the escapement which slackens the running down and regulates it.

It is plain, however, that such a mechanism cannot work with the regularity of a chronometer. Now, we know that red variables never show exact regularity, and that on the contrary their changes in brightness are often very conspicuous. If for the most part they show a much more rapid rise to maximum than fall to minimum (as, for instance, η Aquilæ, R. Cass., T. Vulpec., R. Gemin., Mira Ceti, Mira Cygni, X. Sagitt., etc.), if for the most part their maxima have but a short duration, these common features correspond most exactly with my explanation; but my theory foresees also a quite different behaviour. Slight differences, for instance, in the chemical composition, and misty condensation of different parts of the same cloudy layer, will (also by producing some inequality in the emissive and reflective powers of neighbouring places) cause the cloudy layer not to be dispersed at once, but gradually in process of time. In the latter case the maximum will be neither so bright nor manifest, nor so punctual as in the former. It will be a maximum with fluctuations. The greatest irregularities can be expected, and even a complete loss of periodicity, when the stock of molecules A and B being finally exhausted, other molecules C and D, etc., with different or too little affinity, fill their places. If such great irregularities are not in discordance with my theory, they seem hard to be reconciled to explanations which, like the meteoritic theory of Mr. Lockyer, require a true orbital revolution, usually a very accurate time-keeper.

My explanation is also, I think, in agreement with the spectroscopic observations. In the general obscuration of the minimum spectrum we see the effect of the obscuring clouds, and in the bright lines often observed, especially in the maximum spectrum, the luminous effect of the chemical combination producing a chemical luminescence, there, as well as in our laboratories, where, for instance, at a temperature of less than 150° sulphide of carbon produces a bluish flame with discontinuous spectrum*

* E. Wiedemann: Pogg. Ann. (N. F.) 37, pp. 177—248. R. v. Helmholtz: Die Licht und Warme strahlung verbrennender Gase, Berlin, 1890. E. Pringsheim: Wied. Ann. 45, p. 428; 49, p. 347. Paschen: Wied. Ann. 50, pp. 409—443. G. Wiedemann: Die Lehre von der Elektricität und dem Magnetismus, IV., p. 526. W. Siemens: Wied. Ann. 18, p. 311. Ebert: Vierteljahrschrift d'Astr. Gesellschaft, 1892, p. 34. A. Smithells: Phil. Mag., Jan. 95, Astrophysical Journal, I., p. 266. E. Wiedemann u. G. C. Schmidt: Wied. Ann., 1895, No 4, p. 604. Ebert: Astrophys. Journal, June, 1895, p. 55.

Thus the bright lines at the maximum are not the effect of heat, but rather of cooling, and so we comprehend how it is possible for bright lines to be mostly observed in the atmospheres of those stars which, according to the evidence of their spectra, are to be accounted the coolest.

Now we comprehend also why both the redness of a star and its bright lines must lead to the suspicion of its variability, and we are not at all surprised that numerous variables have been recently discovered by testing that probability.* It is clear, moreover, why neither red stars nor stars with bright lines are *eo ipso* variable. Only these stars will be variable where some vapours in the external atmosphere are cooled to their dew-point, and so are made ready to condense, with the smallest radiation of heat, in obscuring clouds. Stars which are not variable (120 Schj, and D.M.+47°, No. 2291) may have exactly the same spectrum as variables (X Cygni and R Leonis); for it is impossible to admit that identity of spectrum proves exact identity both of chemical composition and of temperature. Even a fall of temperature of 1° would be sufficient, by reaching the dew point of some principal atmospheric vapour, to make a star, hitherto invariable, henceforth variable.

Bright lines point, even in stars of the classes I and II, to great chemical activity in the cooling atmospheres of these stars, so they do also in our sun, which is also more or less a bright line star;† but in the sun, according to my theory,‡ the condensed clouds are not yet obscuring clouds, but still photospheric. Their partial evaporation cannot therefore cause an increase of brightness, but produces, on the contrary, dark spots, whose more or less regular periodicity can be explained therefore in the same way as the greater variability of the already more cooled and chemically more active red stars.

NEBULÆ M. 78 AND H IV. 36 ORIONIS.

By ISAAC ROBERTS, D.Sc., F.R.S.

R.A. 5h. 41m., Decl. N. 0° 1′.

THE photograph covers the region between R.A. 5h. 39m. 24s. and R.A. 5h. 44m. 19s.; Decl., between 0° 59′ North, and 0° 37′ South.

Scale, 1 millimètre to twenty-four seconds of arc.

Co-ordinates for the epoch A.D. 1900 of the Fiducial stars marked with dots.

Star (·). D.M., No. 1073. Zone − 0°. R.A., 5h. 39m. 41·9s. Decl., S. 0° 5·9′. Mag., 9·1.

Star (··). D.M., No. 1178. Zone + 0°. R.A., 5h. 41m. 45·4s. Decl., N. 0° 55·8′. Mag., 8·8.

Star (·.·). D.M., No. 1084. Zone + 0° R.A., 5h. 42m. 21·6s. Decl., S. 0° 31·0′. Mag., 9·5.

Star (::). D.M., No. 1184. Zone + 0°. R.A., 5h. 43m. 37·8s. Decl., N. 0° 42·2′. Mag., 7·5.

The photograph was taken with the 20-inch reflector on January 28th, 1894, between sidereal time 3h. 3m. and 6h. 5m., with an exposure of the plate during three hours.

REFERENCES.

The nebulæ are N. G. C. Nos. 2068 and 2071, G. C. Nos. 1267 and 1270, h 368. Sir J. Herschel (G. C.) describes M. 78 as bright, large, wispish, very gradually much brighter in the middle, three stars involved, barely resolvable. In the *Phil. Trans.*, 1833, Pl. XII., Fig. 36, a drawing of it is given which, in outline, resembles the central part of the nebulosity. The nebula H IV. 36 (N. G. C. No. 2071) he describes as a star with very faint large *chevelure*.

Lord Rosse (*Obs. of Neb. and Cl. of Stars*, p. 51) gives the result of nine observations made between the years 1850 and 1877, and states that a "spiral arrangement is sufficiently seen to confirm former observations." A marginal sketch is given, and a drawing on Pl. I., Fig. 5; but they are not like the photograph, and they fail to indicate the form of the nebula as it is there shown.

The photograph shows the central part of the nebula as a dense cloud, with a well-defined margin on the *north preceding* side, and the three stars referred to by Herschel and Rosse are shown involved in the nebulosity. The star on the northern edge has a faint companion, and faint star-like condensations are also seen involved in the nebulosity. There are flocculent clouds of nebulosity surrounding the dense central part, with wide dark spaces between them, which the descriptive matter and the drawings by Sir J. Herschel and Lord Rosse do not indicate.

The nebula H IV. 36 (G. C. 1270) has a stellar nucleus, with a small companion star close to it on the south side, and this double nucleus is surrounded by cloud-like streaky nebulosity.

The distance between the centres of the nebulæ is about fifteen minutes of arc, and there are indications that the two nebulæ are connected together with very faint nebulosity; but there is no spiral form (as suggested by Lord Rosse) visible in either of them.

The sky within a radius of about half a degree of these nebulæ is remarkably void of stars, but beyond this distance, both *preceding* and *following*, the stars are crowded on the plate.

* E. C. Pickering: Astrophys. Journal, I., p. 27, "Discovery of Variable Stars from their Photographic Spectra." M. Fleming: Astrophysic. Journal, I., p. 411, "Eleven New Variable Stars." Backhouse: Observatory, Febr., 95.

† G. E. Hale: A. and A., 1894, p. 58 (Note on the Spectroscopy at Stonyhurst College Observatory). Miss A. M. Clerke: KNOWLEDGE, Aug., 93, "The Sun as a Bright-line Star."

‡ Theorie du Soleil. Verh. d. Koninkl. Akad. v. Wet. le Amsterdam Decl., I., No. 3, pp., 1—168. A. and A., 1893, p. 914; 1894, pp. 218—237, pp. 849—856.

WHAT IS A NEBULA?

By E. WALTER MAUNDER, F.R.A.S.

THIS question was asked by the late Editor of KNOWLEDGE, some three years ago, and was suffered by him to go without any definite answer. The time that has since elapsed has brought us some details of further information, but still leaves us without any full clue to the solution of the problem. Indeed, if anything, our difficulties are increased, for new and widely extended nebulæ have been discovered where none were previously known, and old nebulæ prove to have a greater extension than had been hitherto suspected.

The difficulty attaching to our understanding the nature of a widely-extended nebula, is very obvious. Such an object as the great nebula in Orion, or the new nebula near Antares, recently discovered by Mr. E. E. Barnard, or the faint wisps that the same observer has found sweeping round the Pleiades, or the still vaster nebulosities in the Cepheus and Cygnus region of the Milky Way, must either be exceedingly close to us, or must have real dimensions of a vastness that baffles the imagination. The first alternative may at once be set aside. Except in a very few cases, we know that the stars are not nearer to us than is implied by a parallax of one-tenth of a second of arc, or a distance more than two million times greater than that which separates the earth from the sun. And the distances of the nebulæ are of the same order as those of the stars. We know this, not only from the numerous examples of evident connection between nebulæ

and stars, but also from that striking relationship discovered by Sir William Herschel in his searches for nebulæ; for, as has been so often quoted, after sweeping through a barren region, he would tell his assistant—"Prepare to write, for nebulæ are coming," as he found himself already on nebulous ground. The two examples of nebulæ which Dr. Roberts furnishes in the present number of Knowledge, stand in just such a typical position, near the debateable line between a region rich in stars, and one comparatively barren of them. Such a relation, repeated over and over again in different parts of the heaven, furnishes the most irrefragable proof, both that nebulæ are situated at the same general distances from us as stars, and that the condensations of stars are not apparent only, but real.

We may be sure, then, that two million times the distance of the sun is the least distance which we can ascribe to them on the average, and that many must be much farther still; yet even at this minimum remoteness, a nebula, whose vaporous arms stretch over 8° of sky, must span within its touch an extent of space greater than that which separates us from α Centauri.

This one fact is sufficient to show how utterly different is the state of things prevailing in the region of the nebulæ from that which prevails in the vicinity of our own solar system. So far as we know, the *lucida* of the Centaur is our nearest neighbour in the heavens, and we know of nothing existing in the mighty void which intervenes between us. A few comets of medium period form, as it were, a feeble fringe to the solar system, of which, otherwise, the orbit of Neptune would mark the boundary. Possibly some of our comets and meteors come to us from the further side of the gulf; but on the whole, the solar system remains a solitary island system, separated from any kindred structure by nine thousand times its own semi-diameter.

> "There sinks the nebulous star we call the sun,
> If that hypothesis of theirs be sound."

And that the Princess's epithet of "nebulous" justly belongs to the sun, when its origin and past history is considered, is generally conceded. But no contrast could be more striking than that between the intense concentration, the almost absolute simplicity, which we see in the solar system, so completely and so widely removed as it is from all neighbouring systems, and the vast far-reaching diffusion of matter seen in such nebulæ as those of the Scorpion of Orion or the Pleiades.

An amusing *jeu d'esprit* published a few years ago claimed to have discovered the mathematics of politics, and to find the geometrical expression of the various forms of government in the conic sections. Reversing this analogy, we may look upon the solar system as a despotism of the strictest kind, a pure autocracy, with the entire power vested in one supreme unchallenged head. The sun exceeds in mass the sum of all his planets and dependents seven hundred and forty-five times. Were they all annihilated the solar system would have suffered loss by but one and one-third parts out of a thousand.

But just as the despotic form of government is not by any means the only one to be found in exercise on the earth, so it is abundantly evident that our solar system is by no means the one universal model on which all systems are constructed. The discovery of such multitudes of double stars, the yet more remarkable cases of the Algol stars, and of the "spectroscopic doubles," show that systems in which the supreme control is divided between two or more bodies are very common.

Nor can we doubt that systems exist which are organized upon what, following the same analogy, we may describe as a thoroughly democratic basis; systems in which there is no one central sun, nor even two or three great bodies, but in which the general mass is distributed not very unevenly between a great number of comparatively small bodies, none of which are large enough to dominate the rest.

Such a system on a vast scale may perhaps be exhibited to us by the superb object which Dr. Roberts has photographed for the October number of Knowledge. The approach to circularity in its outline, and the rapid increase in the condensation of the cluster as the centre is approached, point to its being really, and not merely apparently a globular cluster, and we may take it that its depth in the line of sight does not greatly differ from its length at right angles to it. Its more condensed central and spherical portion has a diameter of about five minutes, which its outlying stars increase to fully twelve minutes of arc. This, with a parallax of one-tenth of a second, would give a diameter to the cluster of two-thirds of a billion miles. This is a little more than one-fortieth of the distance between the Sun and α Centauri. But whereas we have no companion Sun in all that distance, here we find thousands of stars massed together within one cluster. The several stars which make up this cluster must, therefore, be on the average, let us say, about one thousand times closer to each other than are the Sun and α Centauri.

It is, then, in a very different condition as regards the nearness of its component members than we have any experience of in our region of space. And the stars which compose it are of an inferior rank to our sun, if the parallax of one-tenth of a second be adopted. At such a distance our sun would shine like a star of $4\frac{1}{2}$ magnitude, if Mr. Gore's estimate of its actual magnitude as -27 be correct, and four suns as large as our own would give as much light as the entire cluster. Either, then, the individual stars of the cluster are much inferior in intrinsic brightness to our sun, or they must, on the average, be smaller bodies than our earth. A system of about the same total mass as our own, but with the place of the sun taken by thousands of bodies of the size of Jupiter and of our earth scattered over a region two hundred and fifty times the orbit of Neptune in diameter would not represent badly the great cluster in Hercules.

The distance we have assumed is, of course, a minimum. The cluster may be, and probably is, much farther from us, and its components, therefore, larger than we have supposed in the same proportion. But the cluster would remain a cluster still—an association of stars, not greatly dissimilar in size, and, relatively to their size, in pretty close contiguity to each other; and though, in this particular case, we may assign almost any distance we like to the cluster, yet, as Mr. Ranyard has shown in more than one place, we cannot do the same for the Pleiades and for parts of the Milky Way. In these regions we are obliged to conclude that the faintest stars we see are either of very low intrinsic brightness, or else are of the same order as the Earth or Jupiter in the matter of size.

(*To be continued.*)

Letters.

[The Editor does not hold himself responsible for the opinions or statements of correspondents.]

Dr. Roberts' Photographs.

To the Editor of Knowledge.

Sir,—Referring to Dr. Roberts' photographs of 13 M., and the means he suggests for comparing those taken at intervals of eight years for the purpose of detecting

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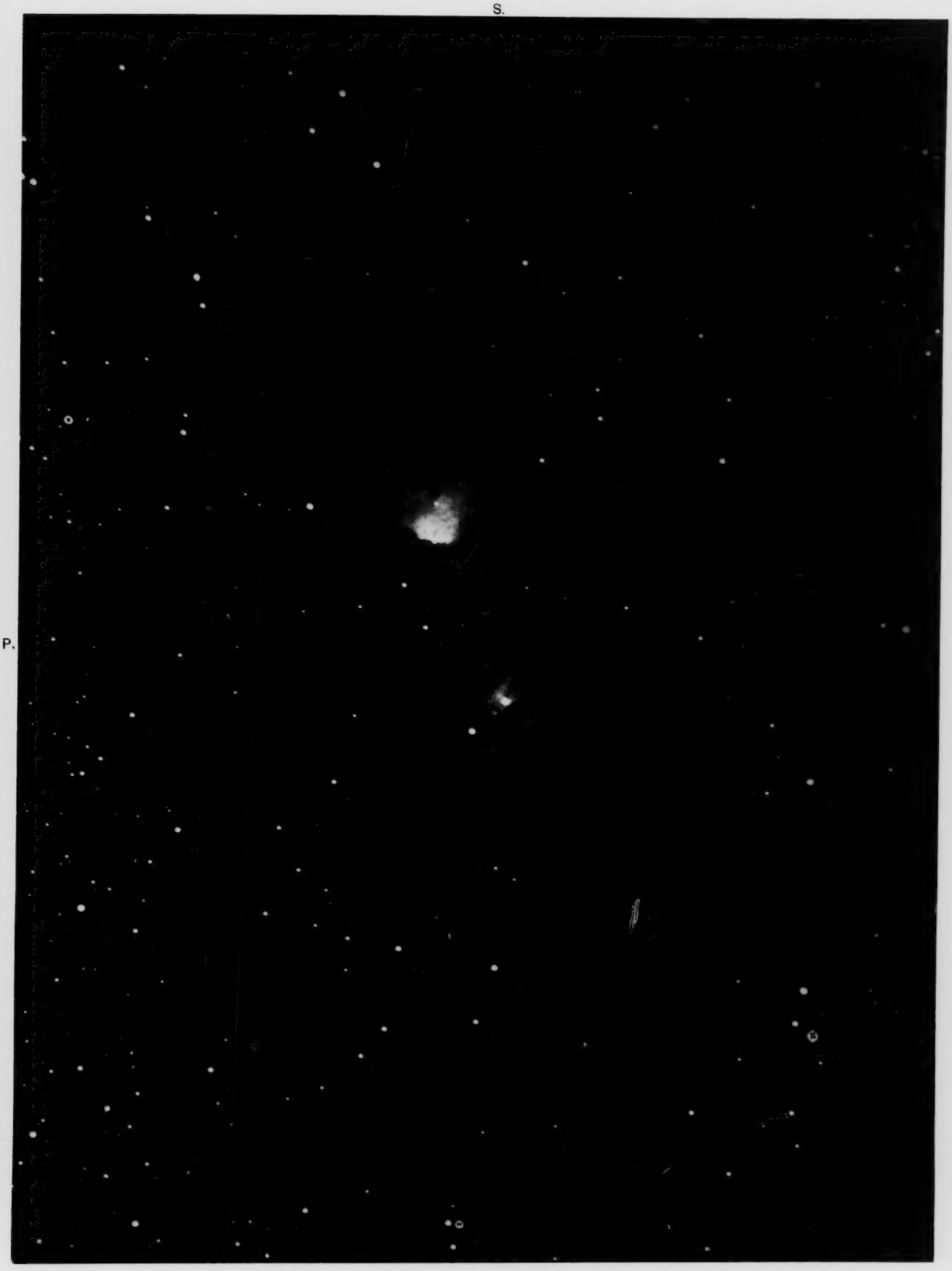
PHOTOGRAPH OF THE NEBULÆ MESSIER 78 AND HERSCHEL IV. 36 ORIONIS.

By ISAAC ROBERTS, D.Sc., F.R.S.

S.



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possible changes, it appears to me that there is another means Dr. Roberts has omitted to notice, which would be easily applied to the whole cluster at a glance. If the two pictures are mounted as a stereoscopic slide and viewed in the stereoscope, any stars which have moved sufficiently will stand out from the picture plane or appear to recede behind it, and a very small motion will be thus easily detected. I do not know if any valid objection exists to this proposal, but, if not, it appears to me the most simple, certain, and readily applied of any.

But there are several preliminary considerations which occur to me upon which Dr. Roberts could enlighten us. Is it certain that two negative films exposed at intervals of years apart will undergo the same deformations during development and after operations? Is the collotype process also reliable to such an extent as to eliminate all danger of accidental displacements? Is the ordinary photographic print reliable in the same way? Is the enlarging process quite certain not to produce any change of relative place. And—not least—the stars are not round on these photographs, and there seems a probability that the deformations may not be in the same direction on different negatives. An illusory displacement would result from this. Besides, the enormous photographic discs tend to mask all changes.

I doubt if any change amounting to one second in eight years is at all likely, but that change is going on is certain, and that Dr. Roberts' photographs will at some future time lead to its detection there can be no doubt.

EDWIN HOLMES.

THE DARK HEMISPHERE OF VENUS.

To the Editor of KNOWLEDGE.

SIR,—During my observations of the planet Venus this summer, I noticed almost invariably, towards the inferior conjunction of the planet with the sun, that its unilluminated hemisphere was distinctly visible, and that it was, moreover, *darker* than the bluish background of the sky itself.

Now, in trying to find a plausible explanation of this remarkable phenomenon, the idea came to me that the appearance might be due to the fact that in such positions the planet is invariably seen projected on the brightest portion of the solar atmosphere, or rather luminous matter surrounding the sun, which, as the zodiacal light teaches us, extends to a very great distance from that luminary.

It is evident that in such a case the dark side of Venus ought to present the appearance actually observed—that of a dusky (violetish) globe, projected on a slightly more luminous background. For even in the case of the solar atmosphere, or luminous envelope, extending farther than the earth's orbit (as the gegenschein would tend to show), the appearances would not be sensibly altered, as the planet would then be seen through the more rarefied portion of the great solar envelope, whilst it would have behind it, or the part on which it would be projected, the brightest and most condensed portion of the same envelope.

The darkness of the unilluminated hemisphere of Venus could hardly be satisfactorily explained otherwise. It could not, of course, be due to phosphorescence, because phosphorescence means light, and light, however feeble, cannot be darker than space itself.

E. M. ANTONIADI.

Constantinople.

HAIRS ON BEES' MANDIBLES.

To the Editor of KNOWLEDGE.

SIR,—My attention has just been drawn to a letter on page 235, by Mr. W. Wesché, headed "Hooked Process on Bees' Mandibles." There is a row of hairs on the inner surface of a worker's jaw, situated along the side of a ridge or keel, and he will find them mentioned and illustrated in Cowan's "The Honey Bee, its Natural History, Anatomy, and Physiology," which is the standard text book used in the examinations for certificates granted by the British Bee-keepers' Association. This is a much more recent work than Cheshire's "Bees and Bee-keeping." Also Schiemenz, in his "Ueber das herkommen des Futtersaftes," mentions and also gives a very accurate illustration of them.

The function of these delicate hairs is to assist in mastication, and they come into operation when the saliva, produced by the gland, known as System IV., in connection with the mandible, is poured out while chewing pollen and kneading wax. They entirely differ in shape from the wing-hooks, and are not twisted like these. They are not used for clustering as suggested. In clustering, bees hang on by their claws, those of the hinder legs of the bee above being hooked into the claws of the forelegs of the one below. The hooks on the smaller wing do not give the name to the Hymenoptera. This name is derived from ὑμήν, a membrane, and πτερον, a wing, meaning membranous winged.

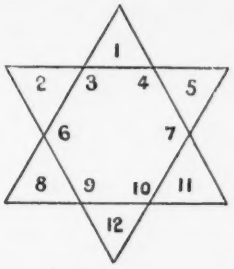
THOS. WM. COWAN.

31, Belsize Park Gardens,
Hampstead, N.W.

THE PUZZLE OF "26."

To the Editor of KNOWLEDGE.

SIR,—I have just received from Mr. T. Ordish, 99, Fore Street, one of his "puzzle of 26," and as it is quite equal to any magic square in the curiousness and harmony of its results, I send you some details which will interest your readers. The discovery is quite new, I believe. It consists of two equilateral triangles intersecting each other



(Natural arrangement of Figures.)

PROBLEM.—Place the numbers 1—12 along the sides of two equilateral triangles interlaced so that they shall add up 26 on each of the six sides, and so that the six numbers round the centre and adjacent thereto shall also make 26.

(as shown above in the "Natural Hexagon" where the numbers 1—12 are arranged in their natural sequence). When arranged thus it forms what might be called the Hexagon, or "Star" of 13. All its diameters, diagonals, 3 great and 3 lesser, sum that number, and the inner and outer circles sum three times 13, or 39. But this is my own idea. Mr. Ordish's puzzle of 26 differs in this, that the numbers 1—12 are arranged so as to sum 26 in 30 different ways, viz., 1 hexagon, 2 triangles, 6 sides, 6 acute angles, 6 obtuse angles, 3 rhombs, 4 rhomboids, and there may be other ways. The outer circle or hexagon sums 52, or double the inner. Perhaps your readers will give the result of their investigations in your next issue, for I believe there are at least six ways of setting the numbers so

as to produce the same results each time. I am aware of only one of these. Would some of your readers also state the *principle* on which they are so arranged?

Brighton. I. G. OUSELEY.

TASMANIAN INSECT PESTS.

To the Editor of KNOWLEDGE.

SIR,—In the copy of KNOWLEDGE of February 1st, 1895, which has just reached my hands, I notice a series of mis-statements which it may be well to correct. I refer to the notice on page 40, beginning with the words:—"The last Australian mails, etc., etc." I am quite at a loss to account for the information reaching you in the form it has, but it is certainly well to place the matter correctly before your readers. It is true that I, as Government Entomologist, did report on the devastations of the various grass-devouring insects, but Mr. Box, who is in no way associated with the Government service, controverted my statements, and some of his remarks, no doubt, found their way into the press. In all the Colonies we suffer a tremendous yearly loss from these grass-pests, and I accordingly have been endeavouring to work out their history and discover some possible remedy. The two underground pests from which we suffer the worst are a variety of cutworm, and the larva of a chafer (*Lachnosterna?*) The former emerge from the eggs deposited by the moths about the end of January (answering to July in the N. hemisphere), and commence their work of destruction by feeding on the tender blades and shoots of grasses, which they frequently drag into the holes made by them, and which vary from six to eight or nine inches in depth, and devour them at their leisure. At the approach of winter they remain in a more or less dormant state, and do not resume their destructive work till the approach of spring. They then gradually mature, change into the chrysalis stage, and after a few weeks emerge as the perfect moth. The beetle-grub, on the other hand, is three years in the ground, and is more or less active during its whole life, excepting during severe snaps of cold or frosty weather. As the perfect beetle it emerges in our midsummer and commits a certain amount of damage to the foliage of fruit trees. We have another pest which is also most destructive, and which is closely analogous to the migrating "army-worm" of American entomologists. It is the larva of a moth *Leucanium*, and as the females can deposit from seven hundred to eight hundred eggs, it is not surprising to find it increasing, under favourable conditions, to an alarming extent. In some years the country is cleared by it. It marches steadily on in vast myriads, and sweeps everything before it. I have heard of the trains being stopped on account of the thousands crushed on the rails rendering them too slippery for the wheels to take grip. I have known of one farmer destroying two tons of them in one paddock by means of trenches and holes, and I have also seen the creeks filled by them two or three feet high in places. Mr. Box's description of the habits of the cutworm are fairly exact, but that gentleman holds that they feed all through the winter, but this, I feel sure, is not invariably the case. All sorts of remedies have been tried and suggested, but without avail. Where irrigation can be carried on, immense numbers of the caterpillars can be destroyed, but this is not always possible. As the result of careful observations I am myself inclined to the opinion that the only method by which we can hope to exterminate these underground pests is by top-dressing with potash salts, and I believe that in kainit we have the best form in which to apply them. Indeed, I am in every way hopeful that we shall be able to check many other pests, such as the scale-insects, aphides, etc., by the use of kainit. I have succeeded in the case of the peach aphis (*Aphis persicæ niger Smith*) and I therefore feel very hopeful about others of the same class of insects as well as the pear-slug (*Lelandria cerasi*), all of which are dependent upon the sap or green tissues of the leaves.

EDWD. H. THOMPSON,
Government Entomologist.

Franklin, Huon, Tasmania
(Entomologist's Branch).

[The note in the February number of KNOWLEDGE referred to by Mr. Thompson, was taken from a Tasmanian paper, and sent to us by a reliable correspondent.—Ed.]

CONCENTRIC RAINBOWS.

To the Editor of KNOWLEDGE.

SIR.—With regard to the appearance of supernumerary rainbows, referred to in your Correspondence columns in the October number, the explanation of these is given by the wave theory of light, and depends on the theory of interference, combined with that of diffraction. An explanation, based on the interference of light, was first proposed by Young in 1804, and was worked out for the first time by Mr. Potter, who published an account of his work in the Cambridge Philosophical Transactions. The final and complete theory was given by Sir George Airy. The problem is a complicated one, and the theoretical conclusions have been experimentally confirmed by Prof. Miller, of Cambridge, who caused a pencil of sunlight to pass in a horizontal direction through a narrow vertical slit and fall upon a thin vertical jet of water. When the stream was observed, portions of the primary and secondary bows and a large number of the supernumerary bows were seen forming a set of vertical coloured fringes arranged side by side. The angular radii of the bows when measured agreed with the value indicated by theory. An account of Airy's theoretical investigation will be found in Preston's "Theory of Light."

I have myself seen on three occasions within a fortnight, while in Strathspey, Inverness-shire, brilliant rainbows with three or four supernumerary bows remarkably well-defined on a very dark background of cloud.

J. J. STEWART.

7, Mountview Road, Crouch Hill, N.

Notices of Books.

Major James Rennell and the Rise of Modern English Geography. By Clements R. Markham, C.B., F.R.S. (Cassell and Co.) Dalton, Liebig, Faraday, Clerk Maxwell, the Herschels, Lyell, Davy, Pasteur, Darwin, and Helmholtz are familiar names in scientific literature; but the same cannot, we fear, be said of that of Major Rennell, notwithstanding Mr. Markham's assertion that "he was undoubtedly the first great English geographer." Mr. Markham has certainly done his best to prove Rennell's right to that position, but even if it be granted, we venture to doubt whether Rennell's work was sufficiently original and striking to interest the public for whom the Century Science Series is intended. Rennell was born in 1742 and died in 1830. He is more remembered for his literary labours than for his work in the field, although, as a matter of fact, Rennell carried out a large amount of real geographical work. His map of Hindostan, and the memoir on the geography of India, which accompanied it, earned him the Copley medal of the Royal Society, and established his position as a working geographer as well as a man of letters. He surveyed and mapped the many ramifications

of the deltas of the Ganges and Brahmaputra rivers, and explored the wild forest region at the base of the Himalayas, while his "Bengal Atlas" is a classical work. But it was as a student of geographical works that Rennell excelled. He brought clear reasoning and high critical powers to bear upon many questions of importance, and elucidated them all by his wide knowledge and indefatigable research. We do not doubt that men like D'Anville, and Ritter, and Rennell (who had a wider experience than either) play a very important part in advancing geography, merely by discussing and systematizing the facts obtained by others. How great and beneficial Rennell's influence upon geography has been can be seen in Mr. Markham's careful and sympathetic sketch of his life and work.

A Text-Book of Zoo-geography. By Frank E. Beddard, M.A., F.R.S. (Cambridge: University Press.) In this admirable addition to the series of Cambridge Natural Science Manuals, Mr. Beddard describes the general facts of the distribution of animals, explains the zoological regions, states the causes which influence the distribution, and discusses some theoretical considerations connected with it. A more accurate, clear, and concise exposition of the facts of zoo-geography could hardly be desired. All who wish to obtain a scientific knowledge of the distribution of the world's fauna could not do better than begin with Mr. Beddard's book.

Ice-Bound on Kolguev. By Aubyn Trevor-Battye, F.L.S., F.Z.S. Illustrated. (Constable.) Up to the time of Mr. Battye's visit, little was known of the island of Kolguev. It was supposed to be inhabited, but even that was considered to be doubtful, while nothing was known of its geological formation, its fauna, or its flora. It was a plucky act on the part of Mr. Battye and his companion to land on this unexplored island with but five weeks' provisions, when the little yacht which had brought them there was forced by the ice and the want of a harbour to leave its coasts. How natives were eventually found, the island explored, its birds and flowers carefully chronicled, and its formation examined, is admirably told in the book before us. If Mr. Battye is a little too colloquial in his expressions, his descriptions are graphic, and the spirit and earnest zeal of the man lend enchantment to his words. His love of birds is manifest on every page of the book, and beyond this he is an accurate and careful recorder, and a good all-round field-naturalist. Moreover, Mr. Battye can draw well, and his book contains a great number of his sketches, and also some fine drawings by Messrs. Whymper, Nettleship and Thornton from his originals. By courtesy of the publishers we reproduce one of the best, illustrating an interesting episode which the author describes in the following words:—"Again the ducks settled down on the water, just on the other side of a small flattish floe. We moved along till we were opposite this, and once more watched. And now, close to the edge of the floe, a seal's head twice appeared. The creature raised itself above the water and looked about, reminding one exactly of a weasel sniffing the air for a mouse when the hunt is momentarily checked. Again the head disappeared. Half a minute more and up rose the ducks for the third time. They rose all but one. There was a flapping of wings on the surface for a moment, and then a duck went below. It seemed as though the bird had been caught by the feet. I never saw the creature land with its capture. . . . . The drama was ended." Mr. Battye and his companion lived during

A HUNTER OF DUCKS. *From "Ice-Bound on Kolguev."*

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a great portion of the time they spent on Kolguev with the Samoyeds, the inhabitants of the island, and collected a great deal of valuable and interesting information as to their customs, habits, and language. The information is rather scattered, and mixed with the events of the day, but this is remedied by a good index and several valuable appendices. Mr. Battye has made no startling discovery, but he has explored a hitherto little known island, and has studied it and its inhabitants, and after all it is this sort of steady work which has real scientific value. We can thoroughly recommend "Ice-Bound on Kolguev" to the general reader. It is bright and interesting, even exciting in parts, but it can only be fully appreciated by the ornithologist.

Object Lessons in Botany. By Edward Snelgrove, B.A. (Jarrold and Sons.) It is a matter of satisfaction to those who are interested in scientific education that the cardinal principle underlying the growth of all true natural knowledge is becoming more and more recognized every day. Cramming is still rampant in our schools and colleges (to the discredit of various examining bodies, be it said, for they are at the bottom of it), but there is a healthy feeling growing that the only scientific instruction worth the name is that which brings the student into personal contact with nature. The book before us carries this idea into practice. It consists of one hundred object lessons suited for standards III. to V. of elementary schools, a volume suitable to standards I. and II. having previously appeared. The book has been carefully planned by an experienced teacher, and will do good work in creating and fostering a love for botanical science.

The Story of the Plants. By Grant Allen. (George Newnes.) Mr. Grant Allen's powers of exposition are very well known, and they have earned for him a high place among British writers, but we are of the opinion that this volume will not add to his reputation as a botanist. What there is in the book is readable enough, but the ground covered is so limited (nearly three parts of the contents being devoted to fertilization and reproduction), and there is such a want of information on many points, that the book can scarcely be regarded as a desirable addition to the literature of even popular science.

The Structure and Life of Birds. By F. W. Headley, M.A., F.Z.S. Illustrated. (Macmillan.) Mr. Headley has chosen a wide field. He treats of the evolution, structure, flight, and life of birds, in a brief and concise manner. At the same time, enough is said on each subject to make the book very valuable to the amateur ornithologist both for reference and study. In the opening chapters the author seeks to show, as so many have done before him, that birds and reptiles have sprung from the same stock; but in our judgment he certainly has not proved his case. The structure of birds, and the functions of their various organs, are well and clearly dealt with. Mr. Headley has a way of making the study of bones and muscles interesting, and his descriptions are greatly aided by a number of excellent illustrations. But, to use the book properly, the student should, in the words of the author, "get dead specimens and dissect them; see the enormous size of the great pectoral muscles; inflate the airsacks . . . . and see how the head is almost a feather's weight, and how the gizzard has taken the place of the grinders that would have burdened it . . . . These, and hundreds of things besides, can only be realized by the aid of dissection." The chapter on flight is a valuable addition to our knowledge of this subject, and the whole book has evidently been well thought out, and is one that should be greatly valued by the lover of birds.

Philips' Handy-Volume Atlas of the World and *Philips' Systematic Atlas.* By E. G. Ravenstein, F.R.G.S. (Philip and Son.) These are two reliable atlases. The first should prove a boon to the traveller. Beyond seventy-two maps and a full index, a page of useful notes accompanies each map. The second has been specially designed for the use of higher schools and private students. The index contains over twelve thousand names, and is clearly set out. The plates adjoining the maps are instructive, showing the languages, geology, vegetation, density of population, etc., of the countries. These plates, together with the fathom lines showing the depths of the seas, should make this atlas of more than ordinary value.

The English Lakes. By Hugh Robert Mill, D.Sc., F.R.S.E. Maps and illustrations. (Philip and Son.) Dr. Mill has done wisely in bringing out in book form his paper "On the Bathymetrical Survey of the English Lakes," read before the Royal Geographical Society last year. It forms a very interesting and highly instructive little book, and is well illustrated with excellent photographs of the district, and diagrams. There are, too, a number of maps showing clearly the depths of the lakes and the heights of the surrounding country. The book should be in the hands of everyone interested in "Lakeland."

BOOKS RECEIVED.

Elements of Modern Chemistry. By Charles Adolphe Wurtz. Fifth Edition. Revised and Enlarged by Wm. H. Greene and H rry F. Keller. (Lippincott Co.) Illustrated.

An Introduction to the Study of Seaweeds. By Geo. Murray. (Macmillan.) Illustrated. 7s. 6d.

Dynamics. By P. G. Tait, M.A. (A. & C. Black.) 7s. 6d.

Movement. By E. J. Marley. Translated from the French by Eric Pritchard, M.A. (Heinemann.) Illustrated. 7s. 6d.

The Scientific Foundations of Analytical Chemistry. By Wilhelm Ostwald, Ph.D. Translated by Geo. M'Gowan, Ph.D. (Macmillan.)

A Popular Handbook to the Microscope. By Lewis Wright. (R.T.S.) Illustrated. 2s. 6d.

A Handbook to the Birds of Great Britain. Vol. II. By R. Bowdler Sharpe, LL.D. (Allen & Co.) Illustrated. 6s.

London University Guide for 1895-6. (Clive.)

Practical Proofs of Chemical Laws. By Vaughan Cornish. (Longmans.) 2s.

Popular History of Animals for Young People. By Henry Scherren. (Cassell & Co.) Illustrated.

Old Farm Fairies. By Henry Christopher McCook. (Hodder & Stoughton.) Illustrated 5s.

Turning Points in Successful Careers. By W. M. Thayer. (Hodder & Stoughton.) 3s. 6d.

Simple Methods for Detecting Food Adulteration. By John A. Bower. (S.P.C.K.) Illustrated.

The Splash of a Drop. By Professor A. M. Worthington, F.R.S. (S.P.C.K.) Illustrated. 1s. 6d.

An Introduction to the Study of Rocks. British Museum (Mineral Department.)

Weather and Disease. By Alex. B. MacDowall, M.A. (Graphotone Co.) Illustrated. 2s. 6d.

The Story of the Heavens. By Sir Robert Stawell Ball, LL.D., F.R.S., &c. Part I. (Cassell & Co.) Illustrated. 6d.

The History of Mankind. By Prof. F. Ratzel. Part I. (Macmillan.) Illustrated. 1s.

Fair Children of the Air: Excursions in the World of Butterflies. By S. H. Scudder. (New York: Houghton, Mifflin & Co.) Illustrated. $1.50.

Illustrated Catalogue of Astronomical Instruments, Observatories, &c. Manufactured by Sir Howard Grubb, F.R.S., F.R.A.S., &c. (Astronomical Instrument Works, Rathmines, Dublin.)

EARTHWORMS.

By C. F. MARSHALL, M.D., B.Sc., F.R.C.S.

THE common earthworm, despised by man and heedlessly trodden under foot, fulfils a part in nature that would seem incredible but for the facts revealed by the patient and long-continued researches of Darwin. "Worms," says Darwin, "have played a more important part in the history of the world than most persons would at first suppose." Let us follow Darwin, and see how this apparently insignificant creature has changed the face of nature. We will first consider the habits and mode of life of the earthworm. As everyone knows, the worms live in burrows in the superficial layer of the ground. They can live anywhere in a layer of earth, provided it retains moisture, dry air being fatal to them. They can, on the other hand, exist submerged in water for several months. They live chiefly in the superficial mould less than a foot below the surface, but in long-continued dry weather and in very cold seasons they may burrow to a depth of eight feet. The burrows are lined by a thin layer of earth, voided by the worms, and end in small chambers in which they can turn round.

The burrows are formed partly by pushing away the earth, but chiefly by the earth being swallowed. Large quantities of earth are swallowed by the worms for the sake of the decomposing vegetable matter contained in it, on which they feed. The earth thus swallowed is voided in spiral heaps, forming the worm castings. In this way the worm obtains food and at the same time excavates its burrows.

In addition to the food thus obtained, half-decayed leaves are dragged into the burrows, mainly for food, but also to plug the mouths of the burrows for the sake of protection. Worms are also fond of meat, especially fat; they will also eat the dead bodies of their relatives. They are nocturnal in habit, remaining as a rule in the burrows during the day and coming out to feed at night.

The leaves dragged into the burrows are moistened by a fluid secreted by the worm, of a digestive nature, and the food is thus partly digested before being swallowed. The digestive fluid of the earthworm resembles the pancreatic juice of higher animals, and only acts when alkaline. Various acids are produced by decaying vegetable matter, and similar changes occur in the leaves swallowed by worms. Now if some of this acid was not neutralized, digestion could not take place, because the digestive fluid is alkaline. This is avoided by the action of some small glands, called the calciferous glands, opening into the alimentary canal. These glands secrete carbonate of lime, which neutralizes the acids generated in the decaying leaves.

The earthworm has no eyes, but is affected by strong light if exposed to it for some time. It has no sense of hearing, but is sensitive to the vibrations of sound. The whole body is sensitive to touch. There appears to be some sense of smell, but this is limited to certain articles of food, which are discovered by the worm when buried in earth, in preference to other bodies not relished. The worm appears to have some degree of intelligence from the way in which it draws the leaves into its burrows, always judging which is the best end to draw them in by. This is remarkable in so lowly organized an animal, being a degree of intelligence not possessed by many animals of more complex organization. For instance, the ant can often be seen dragging objects along transversely, instead of taking them the easiest way.

As we have seen, vast quantities of earth are continually being passed through the bodies of worms and voided on the surface as castings. When it is stated that the number of worms in an acre of ordinary land, suitable for them to live in, is fifty-three thousand, we can imagine the great effect which they must have on the soil. They are, in fact, continually ploughing the land. At one part of the alimentary canal of the worm is a gizzard, or hard muscular organ, capable of grinding food into fine particles; it is this gizzard which is the main factor in triturating the soil, and it is aided by small stones swallowed with the earth, which act as mill-stones. The earth is thus continually passing through the mill formed by the gizzards of worms, and is reduced to fine mould. Again, from the collapsing of the old burrows the mould is in constant slow movement, and its particles rubbed together. Fresh surfaces are thus exposed to the action of the carbonic acid in the soil and to the humus acids, agents which act in the destruction of stones and rocks. Moreover, the acids produced in the digestive tract of the worms is not all neutralized, for the castings have an acid reaction, and this acid acts further in the disintegration of rocks.

Thus all the mould covering a field passes every few hours through the bodies of worms, and the same fragments are probably swallowed and brought to the surface many times over in the course of centuries. Changes are also produced in the slopes of hills by the flowing down of moist castings and the rolling down of dry ones, thus reducing the slope of the hills by accumulations at the bottom. The castings are also blown repeatedly in one direction by the prevalent winds. Now as a layer of earth one-fifth of an inch thick, or ten tons by weight, has been calculated in many places to be brought annually to the surface per acre, if only a small part of this flows down every inclined surface, or is blown by the wind repeatedly in one direction, it is easy to see that a great change may be produced in the surface of the land in the course of ages.

In consequence of the immense amount of earth continually being brought to the surface by worms, it is not difficult to understand how objects, such as stones, rocks, etc., lying on the surface will in course of time become gradually buried in the ground. The worms, undermining the stones, bring up the earth to the surface, and so raise the ground round the edge of the stone till the latter sinks and is eventually buried in the soil, provided the soil is suitable for worms to live in. Darwin showed that in a field covered with flints of various sizes, the smaller ones disappeared in a few years, and in thirty years all had become buried owing to the action of worms.

Owing to the burial of stones and other objects by the action of worms, ancient monuments, portions of Roman villas, and other objects of antiquity have been preserved. These have been gradually buried by the worms, and so preserved from the destructive effect of rain and wind. Many Roman remains were studied by Darwin, and traces of the action of worms found, to which action their preservation was mainly due. The sinking of the foundations of many old buildings is due to the action of worms, and no building is safe from this unless the foundations are laid lower than the level at which the worms can work, viz., about eight feet below the surface.

Another useful effect produced by worms is the preparation of the soil for the growth of seedlings. By their agency the soil is periodically sifted and exposed to the air, and in this way is able to retain moisture and absorb soluble substances of use for the nutrition of plants.

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Moreover, bones are buried by the castings and brought within reach of the roots of plants.

The earthworm is thus seen to be one of the best examples which show how "great effects from little causes spring." This unpleasant-looking and slimy animal, before the days of Darwin, was looked upon as an entirely useless creature, except as a bait for fish and as food for birds.

THE NITROGEN OF THE AIR AS A PLANT FOOD.

By GEORGE MCGOWAN, PH.D.

IN the whole range of agricultural science there is no problem whose solution has presented greater charms, and, it may be added, greater difficulties than the following one—Are plants capable of feeding *directly* upon the nitrogen of the air, or are they not; or, to put the query in other words, can plants assimilate *free* nitrogen, or must their nitrogen be presented to them as food entirely in the form of a nitrogenous compound such as ammonia or nitric acid? The recently published volume for the current year of the *Transactions of the Highland and Agricultural Society* contains a most interesting paper on this subject by Dr. A. P. Aitken, the well-known authority on agricultural chemistry, and we think that we cannot do better than bring a *résumé* of this before the readers of KNOWLEDGE, since it covers within short compass the main points of the whole subject.

Apart from the purely mineral constituents (phosphates, potash, etc.) which plants extract from the soil, they are built up from the four elements—carbon, hydrogen, oxygen and nitrogen, the source of the hydrogen and oxygen being water, and the source of the carbon the carbonic acid of the air. But what about the source or sources of the nitrogen? In the year 1840, Liebig brought out his famous treatise on *Organic Chemistry in its Application to Agriculture and Physiology*, the publication of which, as Dr. Aitken justly remarks, forms the greatest epoch in the history of scientific agriculture. In this memorable work Liebig gives it as his definite opinion that the one source from which plants derive their nitrogen is the ammonia of the air (or its products of oxidation, nitrous and nitric acids). "He dismissed from his mind the idea that plants could take any of their nitrogenous matter from the free nitrogen of the air, because he knew that nitrogen was the most indifferent among the elements (argon and helium being then unknown), and naturally imagined that if plants could make use of free nitrogen, they would not exhibit, as they did, such an avidity for nitrogen in the form of ammonia salts."

But this was a case in which, as we now know, Liebig was mistaken. The first man to make a definite experimental investigation of the subject, such as was fitted to produce results of any value, was the well-known French chemist Boussingault (1802-1886), a contemporary of Liebig, and one of the most eminent among agricultural chemists. His experiments had been in progress for some years prior to the publication of Liebig's great work. He grew plants in an artificial soil containing no nitrogenous matter whatever, the whole being enclosed in a small chamber into which no air was allowed to pass that had not been previously deprived of every trace of the ammonia or other nitrogenous compound that it contained. Under those circumstances, if the plants were to absorb nitrogen, that nitrogen must be the free nitrogen of the atmosphere. These conditions of culture were, however, such that the plants hardly grew at all in the ordinary sense of the word, the whole produce weighing only two or three times as much as the original seeds. As a result, Boussingault found in the ultimate crop—whether of oats, beans, cress, or lupines—no more nitrogen than was originally present in the seeds when they were planted. Notwithstanding the unnatural conditions of growth, however, he was eventually so satisfied with the results of his experiments as to have no hesitation in concluding that plants could *not* absorb free nitrogen from the air, and this opinion, coming as it did from such a distinguished authority, was for long received as correct.

In the year 1849, the late M. Georges Ville, director of the Agricultural Experiment Station at Vincennes, near Paris, began a long and laborious research on the same subject, being of opinion that Boussingault's results were not to be relied upon, inasmuch as the conditions of growth were unnatural, the plants experimented upon having never really entered into an independent state of existence. "He therefore managed his plants in such a manner as to enable them to attain a good normal growth. They were kept under cover, but well ventilated. The soil afforded them was abundant, and contained a certain definite amount of nitrate of soda, and the roots had plenty of room to increase, and they were also provided with good drainage and ventilation. The result was that his plants grew to be ten, twenty, fifty, or one hundred times or more the weight of the seed, *and in their substance they contained more nitrogen than was contained in the seed and the soil together*" (the italics are ours). Since no nitrogenous matter other than the known amount of nitrate of soda in the soil and the free nitrogen of the air had access, M. Ville came to the conclusion that plants, or at least certain plants, could and did assimilate free nitrogen.

Ville's deductions, however, were by no means accepted as correct, being in absolute contradiction to those of Boussingault. The discussion over the point became very warm, and ultimately the French Academy, of which Boussingault was a distinguished member, accepted Ville's offer to appoint a commission to examine his apparatus and superintend his experiments. This commission reported that M. Ville's conclusions were justified by the results he had obtained, but the members composing it were not satisfied that the plants had not been supplied with ammonia as an impurity in the distilled water used for watering them. M. Ville ended his experiments in 1857, and in that year Messrs. Gilbert, Lawes, and Pugh undertook a repetition of Boussingault s experiments at Rothamstead, being careful to conduct these in such a manner as to meet any possible objection that might be taken to any part of Boussingault's procedure. Their results entirely confirmed those of the famous French chemist. Notwithstanding all this, M. Ville still maintained the accuracy of his own results, and published in 1867 a new and extended edition of his researches, in which he reviewed and criticized the work both of Boussingault and of the English experimenters already cited. He maintained that in these the plants suffered from want of ventilation, that they were usually sown at the wrong season of the year, that the quantity of soil used was inadequate, and that—owing to this last circumstance—the mineral manurial matter was too concentrated, and so interfered with the development of the plants. He further pointed out the futility of comparing plants of immature growth with fully developed ones, and also gave some experimental proof for the important statement that "plants do not begin to assimilate the free nitrogen of the air until they have attained a stage of development in which they have acquired at least ten times the weight

of the seed they grew from. He regarded this as the minimum of progress; but, in some of the experiments recorded, it was evident that a later stage of development had to be reached before the power of assimilating the free nitrogen of the air was acquired."

According to Ville, therefore, a certain amount of nitrogenous food must be supplied to plants grown in an artificial soil, in order to bring them to that stage of growth at which they are able to take up nitrogen directly from the air, the amount required depending upon various circumstances. He showed that a certain minimum of nitrogen (*i.e.*, nitrogenous manure) was necessary, and also that there was a certain maximum which must not be overstepped. If this maximum was exceeded, then the plant never drew on the atmospheric nitrogen at all, but preferred to feed on the more easily assimilable nitrate of soda or other nitrogenous matter in the soil. Dr. Aitken adverts to his having "referred at length to Ville's experiments, conducted upwards of forty years ago, and republished by the author about thirty years ago, because, although they were pretty generally discredited at the time, and their results were at variance with those of other more distinguished experimenters, they will be found, as I shall show hereafter, to be a remarkable anticipation of the most recent discoveries regarding the relation of plants to atmospheric nitrogen."

Notwithstanding the fact that Ville's experiments failed to convince the majority of chemists, a suspicion remained in the minds of some that the nitrogen of the air must in some way or other become available for plants, either directly or indirectly. How else was the "balance of nitrogen" in the atmosphere maintained, seeing that there was actual experimental proof that, by the decomposition and combustion of both vegetable and animal matter, a certain proportion of the nitrogenous matter that they contained was constantly being broken up, with the liberation of free nitrogen. And the same thing occurred when nitrates were mixed with soils rich in humus. On the other hand, it was perfectly well known that large quantities of nitrates were lost from the soil in drainage waters. Everything, therefore, pointed to some compensating process or processes by which the free nitrogen of the air was taken up by plants, so as to redress the waste of nitrogenous compounds continuously going on throughout the world. Various natural chemical processes have been suggested at different times as affording the means of this redress—for example, the formation of nitrite and nitrate of ammonium in the air through the agency of the electric discharge during thunderstorms. But it became obvious, after due consideration, that these could only compensate a small part of the loss of the combined nitrogen, and that it must evidently be to some action of plant life that we must turn for an explanation of the riddle. This brings us to a very important paragraph in Dr. Aitken's paper:—"It had been known for many centuries that the growing of leguminous crops was a means of enriching the land in such a manner that after clover, vetches, or the like, an increased yield of wheat or other cereal crop could be obtained; and, since chemistry has come to the aid of agriculture, it has been discovered that the reason why leguminous crops favour the growth of succeeding cereals is that they leave the soil richer in nitrogenous matter than it was before, and this despite the fact that the leguminous crops themselves are distinguished among all other crops by the large amount of nitrogenous matter they contain."

Mention is then made of the important experiment, extending over many years, carried out by Herr Schultz on his property of Lupitz, in Altmark, Germany, which did more than anything else to bring home the above truth to agriculturists; it should just be stated, in passing, that this experiment was originally undertaken with a view of improving poor light soil, and not for any scientific purpose. Herr Schultz came into possession of his property in the year 1855, at which time the land was so poor that it could not grow oats, and, in order to obtain a fair crop of rye, it was necessary to adopt a system of green manuring with lupines. By following Liebig's teaching in applying superphosphate, kainite and marl, all of which are *non*-nitrogenous manures, he found that the lupines responded wonderfully. And the above-mentioned system of green manuring (*i.e.*, of growing lupines or some other leguminous crop one year, and either ploughing these in, preparatory to taking a crop of rye, or cutting the lupines for fodder) had for its result *that the soil became steadily richer in nitrogenous compounds year by year*. It is now forty years since this system was begun, and it is still being continued; and although large crops rich in nitrogenous matter are taken off the ground annually, yet the soil is now three times richer in nitrogen than when Herr Schultz began to work it. "These experiments of Schultz tell us nothing about the source of the nitrogen except that it came from the air, but whether it (this source) was the ammonia of the air or ordinary atmospheric nitrogen could only be a matter of conjecture. Considering, however, the smallness of the store of atmospheric ammonia, and that leguminous plants under manurial treatment show no liking for ammonia salts of any kind, and are apt to be the worse rather than the better for them, even when applied in quantity ten times less than the equivalent of that contained in the crop, it seemed in the highest degree probable that the source of the great gain of nitrogenous matter must be sought for in the free nitrogen of the air."

"The remarkable effects produced by growing lupines and other leguminous plants at Lupitz required to be studied from some other point of view than the merely chemical one"—*i.e.*, from the biological.

The next step towards the solution of the question was the discovery in the year 1877 of the now well-known process of "nitrification" in soils, by two French chemists, MM. Schloesing and Müntz. Of this discovery—a discovery which, as Dr. Aitken remarks, has worked nothing short of a revolution in our method of viewing the relations of the soil to plant life—nothing more need be said here than that it has been abundantly proved by numerous experimenters that complex nitrogenous matters existing in ordinary soils undergo oxidation by the oxygen of the air, first into nitrites and then into nitrates, by the agency of perfectly definite microbes; and some of these latter have been isolated independently, after long and patient endeavours, by Messrs. Winogradsky, P. Frankland, and Warington. The nitrates thus produced by the microbes are then directly available as plant food.

Messrs. Hellriegel and Wilfarth then made a special study of the small tubercles which had long ago been observed in the roots of the lupine and plants of the same order. A microscopic examination of the tubercles showed that they contained bacteria, and a mass of bodies somewhat resembling bacteria and hence called bacteroids, whilst careful experiments proved that these tubercles only made their appearance on the roots of lupines, etc., when the latter were grown in ordinary soil, while plants grown in sterilized soil were free from them. It thus followed that the bacteria had their origin in the soil. The next point to be determined experimentally was, what is the specific effect of these tubercles, or rather of the bacteroids which they contain, upon the growth of the plant? The investi-

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gations entered into with the view of elucidating this led to the following results, the value of which cannot be overestimated, viz., "that when cereals and leguminous plants were grown in a sandy soil to which the requisite mineral manures were added, and the nitrogenous matter given in the form of nitrate, the cereals made growth and attained vigour in direct proportion to the amount of nitrate given to them, when the amount provided was small; so that a double dose of nitrate caused the growth of a two-fold amount of organic matter, a treble dose gave a three-fold increase, and so on until the amount of nitrate had been added which enabled the plants to grow to their normal size, when, of course, the further addition of nitrogen had less and less effect upon the amount of organic matter produced. The cereals were able to assimilate the nitrate *directly*, and their growth in a soil otherwise fertile depended precisely upon the amount of nitrate present. With the leguminous plants no such correspondence was observed. Their growth was quite capricious, and, indeed, sometimes the soil containing the least amount of nitrate produced the largest and healthiest plants. It seemed from many experiments that leguminous plants—such as peas, clover, and lupines—were very little dependent on the nitric acid (*i.e.*, the nitrate) of the soil for their nitrogenous nourishment."

It followed from this that the source of nitrogen for leguminous plants, at all events, must be atmospheric nitrogen, either combined or free; and—not to weary the reader with too many details—it was conclusively established by the experimenters just named that the *free* nitrogen of the air constituted this source. It was further found that the ability of the above order of plants to assimilate free nitrogen was associated in some way with the tubercles in their roots. "Lupines which were grown in sterilized soil, but provided with all the elements of fertility, might grow well enough, but the crop produced contained no more nitrogen than had been provided in the soil and in the seed, and their roots contained no tubercles. On the other hand, when grown in a soil containing very little nitrogen, but in which the micro-organisms associated with the growth of tubercles were present, it was noticed that the plants grew to a certain stature and then began to droop. Cereals grown under similar conditions presented a similar appearance, and eventually died down; but in the case of the lupines, after passing through the drooping stage and losing some of their leaves, they revived, shot out new leaves, and grew at length to full stature. When the crop was analyzed, and also the soil in which it was grown, it was found that *there was a notable increase of nitrogen in both*" (the italics are ours). "This is precisely what Georges Ville found in his experiments thirty years before, and which he described to an incredulous world, and the conclusion he arrived at was the same, viz., that leguminous plants are able to utilize the free nitrogen of the air in building up their tissues." (Of course Ville had not at that time any idea of the agency of micro-organisms here.) The accuracy of Hellriegel and Wilfarth's results has since been thoroughly verified, the assimilation of nitrogen by leguminous plants and the growth of the tubercles having been made the subjects of prolonged study and observation. Much, however, still remains to be found out in regard to this, for, as Dr. Aitken says, while the fact that leguminous plants do assimilate free nitrogen seems to be abundantly proved, the place where the assimilation occurs and the conditions under which it occurs are still matters of conjecture.

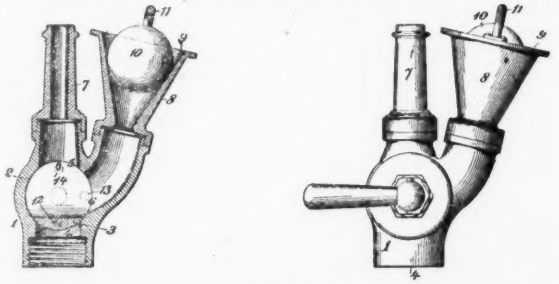
Berthelot has shown further that—altogether apart from the growth of leguminous plants—some *soils* are capable of absorbing the free nitrogen of the air, this being due to the presence of small unicellular algæ. Later researches of Kossowitch, on the other hand, appear to show that algæ have only an indirect, but none the less important, influence upon the process. Prof. Frank, of Berlin, after long study of the subject, has been led to the conclusion that the tubercles on the roots of leguminous plants are not the cause of their ability to absorb free nitrogen, but they are rather the result of that process. He is also of opinion that the seat of the assimilation of free nitrogen is to be found in the chlorophyll cells, where it was long ago proved that the decomposition of carbonic acid by plants and the fixation of its carbon takes place.

"He (Prof. Frank) makes no difference between leguminous plants and others as regards their ability to assimilate free nitrogen in their chlorophyll cells, while he acknowledges that that order of plants possesses the power in a very remarkable degree. He is, therefore, of opinion that while fallow land, poor in organic matter, may become richer in nitrogen through the growth and nitrogen assimilation of minute cryptogams therein, that enrichment is greatly augmented when plants of a higher order are grown upon the land."

From what has been said it will be seen that the whole question of the assimilation of free nitrogen is in a most interesting stage. But the actual and hard-won experimental proof of the fact that the free nitrogen of the air, as such, can be taken up and is taken up by certain kinds of plants, assuredly marks an epoch in the history of agricultural science. Readers who desire to enter into the subject more fully should refer to Dr. Aitken's able paper, for which the thanks of all who are interested in scientific agriculture, but who are precluded through want of time or otherwise from entering minutely into such points themselves, are due.

Some Recent Patents.

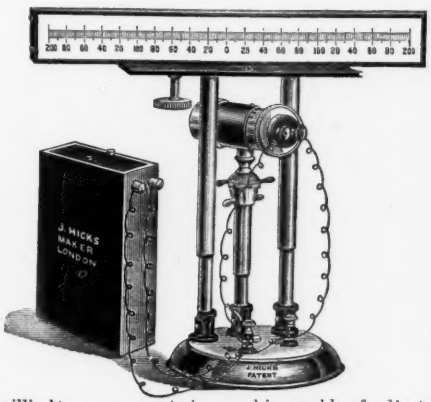
C. and P. Pollock. Connecticut, U.S.A., A. M. Morrell and T. L. Murphy, New York. U.S.A. Devices for spraying water or other fluids. This invention relates to devices for spraying water or other fluids, for extinguishing fires, or for use on gardens, lawns, &c., and consists of a tube having a bell-shaped flaring mouth, within which is a ball of such size as to fill the bell-mouth. A guard, passing across the mouth of the bell, but at such a distance from the ball as to allow the latter considerable freedom of movement, serves to hold the ball in place when the sprinkling device is not in use. This guard, however, has no function while the sprinkling device is in use and water is flowing through it, for the action of the water in passing around the ball is such as to hold the ball firmly in the bottom of the bell-mouth



preventing it from escaping, and this independently of the water pressure. The water in passing around the ball is turned into spray, which forms in drops so large that they are not readily blown away by the wind, nor instantly dissipated by the heat of a fire. The figures show an elevation and section, as constructed for firemen's use, and provided with a straight-stream discharge tip 7, and a spray tip 8. The plug 3 is cut away so as to form a port or passage by which the water may be directed through the straight-stream port 5 or the spray port 6.

No. 11,148. *Dated 6th June*, 1895. *Accepted 17th August*, 1895. *Twelve figures.*

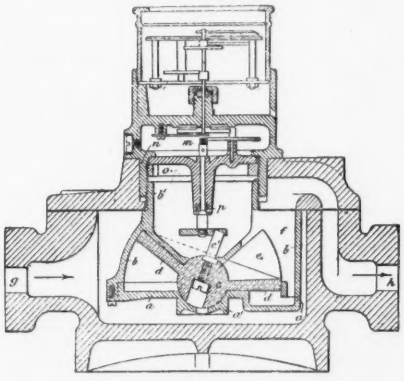
Burstall's Galvanometer Scale and Lamp (Hicks's Patent). The scale and lamp has been designed so as to be portable, rapidly adjusted, and to work in the open daylight. The focussing tube is carried on a ball joint, and by means of a sliding tube can be set at any required height; when the spot of light has been thrown on to the mirror, both these joints can be locked, so that focussing can be done without fear of the spot being shifted off the mirror.



The scale is divided in millimètres on ground glass, and is capable of adjustment both horizontally and vertically, the latter adjustment being by means of a rack and pinion. The source of light is a small glow lamp, worked by two storage batteries. A fine line is etched on the object glass, and this line is focussed on the scale. By means of hinged joints the lamp and scale can be folded into a very small compass. This form of scale and lamp will be very convenient in the laboratory and testing room, and for using with the potentiometer and other portable testing apparatus.

Alfred C. Kemper, 36, Oxford Street, London. The Kombi Camera and Graphoscope combined. This invention consists of an outer metal case, 2 inches by 1½ inches, fitted with a lens having two stops. The interior contains two film holders fitted with a platen for the purpose of stretching that portion of the surface of the film upon which the exposure is to be made and a mat for determining the size and shape of the picture. The camera holds a roll of twenty-five films. Time or instantaneous exposures may be made with an ingenious shutter attached to the fore part of the machine. By removing a cap-plate at the back the machine can be used as a graphoscope.

Walter George Kent, High Holborn, London. Improvements in disc engines, particularly suitable as water meters. The working chamber or so-called cylinder is formed in two parts, *a* and *b*, the bottom *a* being a flat dish with a cylindrical boss a^1 on its underside, to provide for the reception of the ball *e* at the centre of the disc or piston *d*. The sides of the upper part *b* of the cylinder are formed of a portion of a sphere, and the top consists of an inverted conical frustum. The inlet and outlet pipes *g* and *h* are diametrically opposite to each other, and the inlet and outlet ports *j* and *k* to the cylinder are formed as usual on each side of the partition *r*. The gearing working the counting and recording apparatus is contained in an oil-filled box *m* carried by the cover of the outer casing.



No. 18,286. *Dated 26th September*, 1894. *Accepted 17th August*, 1895. *Seven figures.*

Chess Column.

By C. D. LOCOCK, B.A.Oxon.

Communications for this column should be addressed to C. D. LOCOCK, Burwash, Sussex, and posted on or before the 12th of each month.

Solutions of October Problem.

(J. T. Blakemore.)

Key-move.—1. Kt to Kt3.

If 1. . . . K to Q5, 2. R to KR4, etc.
1. . . . K to B3, 2. R to KR4, or 2. B × Pch, etc.

It is most unfortunate that the removal of a White Pawn at QR4, just before publication, has given rise to the above dual, which, by the way, has not been detected by any solver. The alteration was suggested by the Chess Editor, and approved by the Composer, whose subtle continuation, 2. R to KR4 in reply to 1. . . . K to B3, has thus escaped notice and appreciation.

CORRECT SOLUTIONS have been received from Alpha, H. S. Brandreth, G. A. F., A. C. Challenger, A. H. Walker, W. Willby, E. W. Brook.

M. Wiedhafft.—In reply to 1. Kt to KB4ch Black would play 1. . . . K to Q5. There is then no mate in two more moves.

J. T. Blakemore.—We much regret that though we pointed out one dual we were chiefly responsible for another.

A. C. Challenger.—Many thanks. The 3-mover appears below. The sui-mate is reserved for next month.

G. A. F.—A capture on the opening move is considered a rather serious blemish, especially if the captured piece was free to move, the diminution of the opposing force being inartistic. A problem of this class is liable to baffle the experienced solver, who naturally tries the checks and captures only when everything else has failed. The promotion of a Pawn increases the value of the White force, but does not increase it *numerically*. Hence the queening of a Pawn is not usually objected to, unless it occurs as the key-move; still it is best to avoid it when possible.

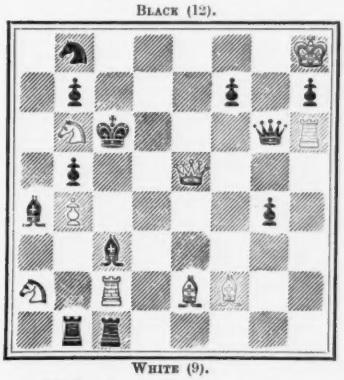
T. A. Brock.—Thanks for the problem, which has a distinct and refreshing savour of originality.

PROBLEMS.

No. 1.

By T. A. BROCK.

BLACK (12).



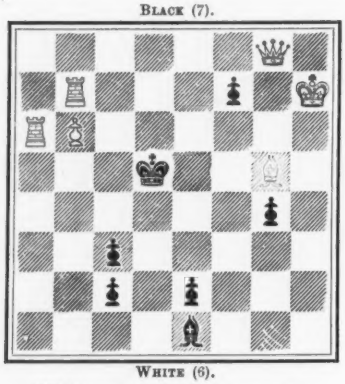
WHITE (9).

White mates in two moves.

No. 2.

By A. C. CHALLENGER.

BLACK (7).



WHITE (6).

White mates in three moves.

We give below another game played in the recent International Tournament at Hastings.

"Ruy Lopez."

WHITE. C. v. Bardeleben.	BLACK. Dr. Tarrasch.
1. P to K4	1. P to K4
2. Kt to KB3	2. Kt to QB3
3. B to Kt5	3. P to QR3
4. B to R4	4. Kt to B3
5. Castles	5. P to Q3
6. Kt to B3	6. P to QKt4
7. B to Kt3	7. B to Kt5
8. Kt to K2	8. B × Kt
9. P × B	9. Q to Q2
10. P to QR4	10. Q to R6
11. P × P	11. P to KR4
12. R to Ksq	12. Kt to KKt5
13. BP × Kt	13. KRP × P
14. B × Pch	14. K × B
15. R to R3	15. Q × Pch
16. K to Bsq	16. P × P
17. R to KKt3	17. KR to R3
18. P to Q3	18. R to B3
19. B to K3	19. B to K2
20. R to Kt2	20. Q to R5
21. Kt to Kt3	21. R to B6
22. K to K2	22. Q to B3
23. Kt to B5	23. R to KR6
24. K to Q2	24. R to KR2
25. Q × P	25. B to Bsq
26. Q to B3	26. K to Ksq
27. R(Ksq) to KKtsq	27. Q to B2
28. Q to Kt4	28. Kt to K2
29. Kt to R4	29. Kt to Ktsq
30. Kt to Kt6	30. Kt to B3
31. Q to B5	31. Kt to Ktsq
32. Q × Qch	32. K × Q
33. R to KBsq	33. B to K2
34. Kt × B	34. K × Kt
35. R(Kt2) to Ktsq	35. K to Q2
36. R to QRsq	36. R × R
37. R × R	37. Kt to K2
38. R to R7	38. R to Rsq
39. K to K2	39. Kt to B3
40. R to Rsq	40. K to K3

Drawn Game.

After escaping from Dr. Tarrasch's violent attack, Herr von Bardeleben did not seem disposed to tempt fortune further. He was afterwards apparently content to play to draw a game which he might, perhaps, have won.

CHESS INTELLIGENCE.

Some weeks ago, at Hastings, M. Tschigorin announced that the St. Petersburg Chess Club offered valuable prizes for a tournament to be played in that City in the autumn, the competitors to consist of the five chief prize winners at Hastings, who were to play four or five games with each other. Such a tournament would be very interesting as the happy mean between match play and tournament play, but it does not appear that the details are at present settled. In the meantime Mr. Pillsbury is being lionized in America; but Messrs. Lasker, Tarrasch, Steinitz and Tschigorin are still on the Continent, awaiting the event.

Messrs. E. O. Jones and Herbert Jacobs, two of the strongest British amateurs, have just concluded a match, Mr. Jones winning rather decisively by five games to one, three games being drawn. The winner is the present holder of the Craigside Challenge Cup, his opponent being the previous holder of the trophy.

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TWO PLATES.—1, Nest of Young Kestrel Hawks; 2, Photographs of the Globular Cluster, Messier 13 Herculis.

NOTICES.

The numbers of KNOWLEDGE for January and February of last year can now be had, price One Shilling each.

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